SCIENTIFIC AGRICULTURE

VOLUME 31 MAY, 1951 No. 5

A STUDY OF METHODS OF INFLUENCING LODGING IN BARLEY AND THE EFFECT OF LODGING UPON YIELD AND CERTAIN QUALITY CHARACTERISTICS[1]

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[Received for publication November 30, 1950]

INTRODUCTION

Many investigations have been carried out in an attempt to determine the cause of lodging. The problem has been approached from the point of view of soils and fertilizers, root structure, and stem morphology. It is common knowledge that lodging causes reduced yields and lower bushel weight but little work has been done to determine the degree to which lodging affects yield and quality.

The effect of lodging in test plots is of great importance because of its probable effect on quality. In a cereal breeding program in which quality factors are being considered, the lodging of some strains, due to their weak straw, may adversely affect their quality. This might result in very high quality hybrids, which would be of value as parent material, being overlooked entirely. If information on the effect of lodging in cereals were available some adjustment of quality data could be made for plots which had lodged.

In order that an accurate assessment of quality may be made, it is desirable to have the strains being tested in as upright a position as possible. Therefore, technique that might be applied to control lodging would have real value.

REVIEW OF LITERATURE

Few data on the effect of rate of seeding and amount of spacing between rows on lodging have been published. Numerous authors (2), (8), (10), (12), however, refer in general terms to the fact that more lodging occurs at heavier rates of seeding. Leith and Delwiche (7) state that oats seeded at higher rates lodged while those at lower rates did not. In 1919, they found that at a seeding rate of 3 bushels per acre, 100 per cent of the crop lodged, at 2 bushels, 33 per cent lodged, and at 1 bushel there was no lodging. In 1921 and 1922 similar results were obtained.

Harlan and Martini (5) and Welton and Morris (12) refer to the fact that early lodging will affect the development of the kernels to a greater extent than will lodging at a later date.

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Data on the effect of lodging in wheat are given by Egorov (3). In 2 fields of wheat 3 samples were taken: 1. Non-lodged plants. 2. Plants from the top layer of the lodged areas. 3. Plants from the bottom layer of the lodged areas. He found that lodging reduced values for head length, head diameter, weight of 100 heads, 1000 kernel-weight, yield and a measure equivalent to weight per bushel. Ratio of protein to starch in normal grain was 1 : 4 while in lodging grain it was 1 : 2.7.

No reference to the artificial lodging of cereals could be found; however, Tysdal (11) artificially lodged alfalfa plants by gently forcing the stems over and holding them near the ground with wire staples.

MATERIAL AND METHODS

Six varieties of barley were used in both parts of this study. In selecting them an attempt was made to cover the range of straw strength as well as possible. Sanalta was used to represent the strong strawed group; Montcalm, O.A.C. 21, Plush and 41-1522 (a University of Manitoba hybrid) the intermediate group, and Wisconsin 38 the weak group.

In order to simulate weather conditions favourable to lodging a small overhead irrigation system was installed. This was used often enough to give the luxuriant type of growth usually associated with severe lodging. A total of approximately 12 inches of water was received by the plots during the growing season each year.

The Effect of Rate of Seeding, Spacing and Type of Guard Row on Lodging in Rod Row Plots

The treatments in this phase of the experiment were as follows: The six varieties mentioned above; rates of seeding equivalent to $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ bushels per acre; spacings between rows of 9, 12 and 15 inches; and three types of guard row, namely, the same variety as the test plot, Sanalta barley and Renown wheat.

A split plot design was used, varieties being placed in the largest plots, types of guard row randomized within the variety plots and rates of seeding and spacing between rows randomized with the guard row plots. Two replicates were planted.

All plots consisted of 4 rows thirteen feet long, 1 foot being cut off each end before harvesting. The 2 middle rows were used for making all determinations.

Data on straw strength were obtained by means of lodging index similar to that used by Clark and Wilson (1). The index was arrived at by multiplying the strength of straw recorded on a 1 to 10 basis (1 being flat on the ground and 10 upright) by the percentage of the plot having that straw strength, summing the values for each plot and dividing by 100.

This phase of the work was carried out in 1946, 1947, and 1948.

The Effect of Artificial Lodging on Yield and Various Barley Kernel Characters

In this part of the experiment the same 6 varieties of barley were used. Plots consisted of 6 rows thirteen feet long, 1 foot being cut off each end before harvesting. All data were obtained from the middle 2 rows.

While no precedent seems to have been established with regard to the artificial lodging of cereal crops, it was decided to not rely on natural factors to induce lodging.

In 1946, 2 degrees of lodging were used: Flat on the ground, and upright. Complete lodging was accomplished by irrigating the plots for a number of hours and then gently pushing the plants down, using a length of board which enabled all 6 rows of each plot to be lodged at the same time. All possible care was taken to prevent damaging the stems or disturbing the roots. The lodging was performed at 3 dates—1 week, 2 weeks, and 3 weeks after heading.

In 1947, 1948, and 1949 another degree of lodging, an angle of approximately 45°, was included. The different degrees of lodging were accomplished in the following manner: A piece of 2-inch mesh wire netting, approximately the same size as the plot, was supported horizontally at a level 18 to 24 inches above the ground. The barley grew up through this netting. The plots that were to remain upright were not disturbed. To obtain the 45° angle the wire was pulled carefully in the horizontal plane and secured in such a position that the plants were at the required angle. Complete lodging was accomplished by gently forcing the plants over and then placing the wire on top of the plants and securing it so that the plant remained flat on the ground. It was not possible, however, to prevent the stems of the plants from bending at the nodes during subsequent growth thus placing the heads in an upright position above the wire.

The above treatments were carried out at heading, 10 days after heading and 20 days after heading. Although some damage to the plants could hardly be avoided, satisfactory control of lodging was obtained by this method.

Yield, 1000 kernel-weight, weight per measured bushel and nitrogen content of the grain were determined.

RESULTS AND DISCUSSION

The Effect of Rate of Seeding, Spacing Between Rows and Type of Guard Row Upon Lodging in Rod Row Plots

When this part of the experiment was set up it was decided that information on the differences between varieties would not be of any particular value. The design of the experiment was such that the error to which varieties would be compared was likely to be large and no significant

TABLE 1.—EFFECT OF TYPE OF GUARD ROW ON YIELD AND STRAW STRENGTH 1946-1947-1948

Type of guard row	Yield (bushels per acre)	Straw strength index
Same as plot	45.4	4.26
Sanalta	46.1	4.72
Wheat	57.7	5.08
L.S.D. at the 5 per cent level	3.5	0.54

differences were expected. In the analysis of the data none of the interactions involving varieties was found to be significant and hence all references to varieties will be omitted from the discussion.

The data presented in Table 1 show the effect of the various types of guard row on yield and straw strength. The outstanding feature of these data is the increased yield and straw strength obtained from the plots which had wheat guard rows. The high value for straw strength was obtained because the 2 centre rows of the plot, although they had weak straw, in many cases were held in a relatively upright position by the stronger strawed wheat guard rows. The same was true, to a much lesser extent, when the strong strawed barley, Sanalta, was used for guard rows. The increased yield for plots with wheat guard rows may be partially accounted for by the higher straw strength index. The relative competitive ability of these two cereals may also account for some of the yield increase.

The data in Tables 2 and 3 indicate that heavier seeding rates tend to give lower yields and weaker straw. Significant differences in straw strength was obtained between all rates of seeding studied. The 15-inch spacing had significantly weaker straw than did the other 2 spacings.

TABLE 2.—EFFECT OF RATE OF SEEDING AND ROW SPACING ON STRAW STRENGTH (1-10) 1946-1947-1948

Spacing between rows (inches)	Rate of seeding (bushels per acre)			Spacing means
	1½	2	2½	
9	5.33	4.90	4.58	4.93
12	5.41	4.71	4.18	4.77
15	4.68	4.47	3.94	4.36
Rate means	5.14	4.69	4.23	

L.S.D. at the 5 per cent level:
For spacing means — 0.31.
For rate means — 0.31.
For rate × spacing interaction — 0.53.

TABLE 3.—EFFECT OF RATE OF SEEDING AND ROW SPACING ON YIELD (BUSHELS PER ACRE) 1946-1947-1948

Spacing between rows (inches)	Rate of seeding (bushels per acre)			Spacing means
	1½	2	2½	
9	56.1	53.5	50.6	53.4
12	51.8	49.2	46.6	49.2
15	47.1	47.4	45.2	46.6
Rate means	51.7	50.1	47.5	

L.S.D. at the 5 per cent level:
For spacing means — 3.0.
For rate means — 1.7.
For spacing × rate interaction — 3.0.

There was no significant difference between the 9- and 12-inch spacing as far as straw strength was concerned. Table 2 shows a decrease in straw strength as the seeding rate and spacing between rows increase.

In Table 3 a decrease in yield is noted as the rate of seeding and spacing between rows increases. The highest and lowest values for each of these 2 variables are significantly different. The decrease in yield obtained here may be partly accounted for by the weaker straw in the plots seeded at heavier rates.

None of the other components of variance reveals anything that disagrees with the above statements. None of the interactions involving varieties or years was significant.

The over-all results indicate that when conditions are similar to those under which this experiment was conducted, maximum yield and strongest straw will be obtained in rows seeded 9 inches apart at a rate of $1\frac{1}{2}$ bushels to the acre. This general statement applies to all varities used in the study except Sanalta. This large kernelled, 2-rowed barley showed higher yields at 2 bushels per acre in 2 years out of 3. In 1948 it behaved in a manner similar to the other varieties.

The Effect of Artificial Lodging on Yield and on Various Barley Kernel Characters

1946

The results for this experiment in 1946 are given in Table 4. It will be noted that yield, 1000 kernel-weight and weight per bushel decreased as the length of time the plots were lodged was prolonged. The reverse was true in the case of nitrogen, the values decreasing as the lodging was prolonged. In no case did lodging three weeks after heading give values significantly different from the check plots although the difference was always in the direction expected. In all cases the most severe treatment was the earliest date of lodging. One notable feature is the high necessary difference for the data on yield. This may be accounted for by the fact that there was a significant interaction between varieties and date of lodging. This may be due to the fact that the yield of naturally weak strawed varieties was not affected as much by early lodging as was that of the naturally strong strawed varieties. Some support is given to this thesis by the behaviour of the weak strawed Wisconsin 38, which is pointed out in the discussion following Table 6.

TABLE 4.—EFFECT OF DATE OF COMPLETE LODGING ON YIELD PER ACRE, THOUSAND KERNEL-WEIGHT, WEIGHT PER MEASURED BUSHEL, AND NITROGEN CONTENT 1946

Factor	Date of lodging			Check	L.S.D. at the 5 per cent level
	One week after heading	Two weeks after heading	Three weeks after heading		
Yield (bushels per acre)	47.1	54.7	68.9	71.8	18.1
1000 kernel-weight (grams)	33.22	35.87	38.43	39.23	1.28
Weight per bushel (lb.)	45.4	46.6	48.8	49.5	0.8
Nitrogen (per cent)	2.37	2.30	2.20	2.15	0.08

1947-1949

Yield

Table 5 gives the results for the effect of degree and date of lodging on yield. The data presented were obtained from the analysis of results for the years 1947 and 1949 combined. In 1948 some plots were rather severely damaged by sparrows and as a result the yield data were of practically no value, and therefore were not used.

TABLE 5.—EFFECT OF DATE OF LODGING AND DEGREE OF LODGING ON YIELD (BUSHELS PER ACRE) 1947 AND 1949

Degree of lodging	Date of lodging			Lodging means
	At heading	Ten days after heading	Twenty days after heading	
Complete lodging	22.3	25.7	33.6	27.2
Forty-five degrees	47.1	52.6	56.8	52.2
Upright	64.5	63.2	64.5	64.0
Date means	44.6	47.1	51.6	

L.S.D. at the 5 per cent level:
For lodging means — 7.0.
For date means — 3.9.
For lodging × dates interaction — 6.8.

There are 2 outstanding features of the data in Table 5. First, the large differences obtained between the lodging means; and second, the fact that at all dates of lodging the 45-degree treatment gave significantly lower values than the check plot. It is rather surprising that lodging to a 45-degree angle 20 days after heading (which is approximately 10 days before maturity at Winnipeg) resulted in a significantly lower yield than no lodging.

Table 6 shows the effect of the various treatments on the individual varieties.

TABLE 6.—EFFECT OF DEGREE OF LODGING ON THE YIELD OF INDIVIDUAL VARIETIES (BUSHELS PER ACRE) 1947 AND 1949

Variety	Degree of lodging		
	Complete lodging	Forty-five degrees	Upright
Montcalm	21.3	51.1	66.8
Plush	27.6	52.0	74.8
O.A.C. 21	28.4	56.2	66.4
Sanalta	28.0	42.9	55.4
Wisconsin 38	30.2	49.1	58.9
UM 41-1522	27.6	61.8	62.0

L.S.D. at the 5 per cent level:
For within variety comparisons — 6.8.
For within degrees of lodging comparisons — 11.1.

It will be noted that the reaction of all varieties to the various treatments was similar. The significance of the lodging × varieties interaction may be accounted for by the fact that the order of yield of the varieties under the various treatments changed. The weak strawed variety Wisconsin 38 appears to be the highest yielding under complete lodging but when in an upright position, a number of other varieties appear to outyield it.

Thousand Kernel-weight

In Table 7, 1000 kernel-weight data are given. These figures were obtained from the combined analysis of the data for 1947, 1948, and 1949.

TABLE 7.—EFFECT OF DATE OF LODGING AND DEGREE OF LODGING ON THOUSAND KERNEL-WEIGHT (GRAMS) 1947-1948-1949

Degree of lodging	Date of lodging			
	At heading	Ten days after heading	Twenty days after heading	Lodging means
Complete lodging	28.63	29.20	30.34	29.39
Forty-five degrees	32.54	30.94	33.42	32.30
Upright	34.05	35.53	34.76	34.78
Date means	31.74	31.89	32.84	

L.S.D. at the 5 per cent level:
For lodging means — 1.42.
For date means — 1.42.
For lodging × date interaction — 2.45.

As in the case of the yield results, large differences occur between the lodging means. None of the differences between date means is significant. Similarly none of the differences between dates within each lodging treatment is significant. In fact, the value obtained for the 45-degree treatment at heading is higher than that obtained for the same treatment at 10 days after heading. This does not agree with the yield results for these same treatments. A probable explanation is offered later in the paper. There was no significant interaction of any of the treatments with varieties.

Nitrogen Content

Data obtained on nitrogen content under the various treatments are presented in Table 8. Again a very significant difference between degrees of lodging was obtained, the nitrogen content increasing as the severity of lodging was increased. There are no significant differences between the date treatments although the check plot appears to be slightly lower than the 2 treated plots. The nitrogen content for the "45-degree at heading" treatment is slightly lower than that for the "45-degree—10 days after heading" treatment. This was not expected. It does, however, agree with the 1000 kernel-weight figure for the same treatment. The explanation is the same as that which is offered later for the 1000 kernel-weight figures for these treatments.

TABLE 8.—EFFECT OF DATE OF LODGING AND DEGREE OF LODGING ON NITROGEN CONTENT (PER CENT) 1947-1948-1949

Degree of lodging	Date of lodging			
	At heading	Ten days after heading	Twenty days after heading	Lodging means
Complete lodging	3.11	3.08	2.94	3.04
Forty-five degrees	2.74	2.78	2.69	2.73
Upright	2.58	2.58	2.63	2.60
Date means	2.81	2.81	2.75	

L.S.D. at the 5 per cent level:
For lodging means — 0.09.
For date means — 0.09.
For lodging × dates interaction — 0.15.

Weight per Bushel

On account of accidents the crop from a number of the plots in 1948 and 1949 was destroyed before weight per bushel data were obtained, leaving so many gaps that statistical analyses could not be made. Therefore only the 1947 results are available. These are presented in Table 9.

TABLE 9.—EFFECT OF DATE OF LODGING AND DEGREE OF LODGING ON WEIGHT PER MEASURED BUSHEL (POUNDS) 1947

Degree of lodging	Date of lodging			
	At heading	Ten days after heading	Twenty days after heading	Lodging means
Complete lodging	39.7	38.2	41.0	39.6
Forty-five degrees	42.7	42.6	43.6	43.0
Upright	46.2	46.4	46.0	46.2
Date means	42.9	42.4	43.6	

L.S.D. at the 5 per cent level:
For lodging means — 1.3.
For date means — 1.3.
For lodging × dates interaction — 2.2.

Again a very significant decrease was obtained in the more severe lodging treatments. This is noticeable at each date as well as in the overall means for the lodging treatments. The difference between dates is not significant.

Here, as in the case of 1000 kernel-weight, Table 7, the value for "at heading" under 45° lodging is as high or slightly higher than that for 10 days after heading. In the case of nitrogen, the value for the "at heading" treatment is lower than that for the "10 days after heading" treatment. These results can be explained by the fact that while the plots lodged at heading were lodged the required amount, as growth progressed some of the plants turned upward at a node. Although the straw of the plant

behind this node was at the desired angle, this bending elevated the heads and allowed them to develop in a fairly normal manner. All threshed samples were run through a fanning mill to remove straw and chaff before the data were recorded. This probably resulted in removal of a considerable proportion of light weight kernels that were produced on those plants that remained lodged throughout their extent. This would have the effect of increasing the 1000 kernel-weight and test weight per bushel, and lowering the nitrogen content. On the other hand, it would aggravate the reduction in yield under this treatment because the total weight of grain produced would not be recorded.

The results indicate that as artificial lodging becomes more severe and as it occurs at earlier dates, the decrease in yield, weight per bushel and 1000 kernel-weight becomes greater. Even lodging to a 45° angle as late as 20 days after heading may cause a significant decrease in these values. Under similar treatments the nitrogen content increases. These results in general agree with the following statement by Welton and Morris (12): "Lodging may affect both the quantity and quality of the crop, the degree of loss varying with the completeness of the falling, the state of development at which it occurs, and the subsequent weather conditions. If lodging takes place at an early stage the loss is greatest, for it then results in the development of shrivelled, shrunken kernels of light weight."

The results for varieties has in general been omitted from the above discussion. In no case did any significant interaction involving varieties conflict with any of the statements made. The capacity of the various varieties to yield under lodged conditions varied but in most cases more severe lodging treatments applied within a variety resulted in a decrease in yield, weight per bushel and 1000 kernel-weight and an increase in nitrogen content.

In most instances clear-cut differences between date means were not obtained. The design of the experiment may in part account for this fact. Complete lodging and 45° lodging applied 10 days after heading would be expected to give a higher yield than the same treatments applied at heading. However, the date means include the upright treatment as well as the 2 just mentioned. The upright plots are all actually check plots. One of these check plots enters into each date mean and as a result the percentage difference between date means is less than one might expect. If comparisons are made within the interaction table, rather than between the over-all date means, a better interpretation of the results can be made. For example, in Table 5 under complete lodging the "10 days after heading" treatment gave a 15.2 per cent increase in yield over the same treatment applied at heading. The 45° treatment applied at the same dates gave an 11.7 per cent increase. The date means, however, show an increase of only 5.6 per cent.

SUMMARY AND CONCLUSIONS

1. The use of lodging resistant guard rows on rod row plots tended to prevent lodging and thus increase yield, regardless of variety.

2. Heavier rates of seeding and wider row spacing resulted in weaker straw and reduced yields.

3. As artificial lodging became more severe and as it occurred earlier in the period from heading to maturity, the decrease in yield, weight per bushel and 1000 kernel-weight became greater. Under similar conditions the nitrogen content of the kernels increased.

4. Even lodging at a 45° angle as late as 20 days after heading may have a significant effect on yield and kernel characters.

REFERENCES

1. Clark, E. R., and H. K. Wilson. Lodging in small grains. J. Am. Soc. Agron. 25 : 561-572. 1933.
2. Donald, G. Some factors influencing the standing power of oats. Scottish J. Agr. 18 : 34-40. 1935.
3. Egorov, D. V. Lodging of spring wheat under irrigation. Socialistic Grain Farming, Saratov 1 : 84-102, 1938 (in Russian).
4. Goulden, C. H. Statistical methods for research workers. John Wiley and Sons, New York. 1939.
5. Harlan, H. V., and M. L. Martini. Problems and results in barley breeding. U.S.D.A. Yearbook, 1936.
6. Harper, H. J. Effect of row spacing on the yield of small grain nurse crops. J. Am. Soc. Agron. 38 : 785-794. 1946.
7. Leith, B. D., and E. J. Delwiche. Wisconsin oats. Wisc. Agr. Exp. Sta. Bull. 340. 1922.
8. Percival, J. The wheat plant. Duckworth and Co., London. 1920?
9. Rayns, F. An experiment in the seeding of barley. J. Roy. Agr. Soc. England 91 : 95-109. 1930.
10. Thayer, J. W., Jr., and H. C. Rather. The influence of rate of seeding upon certain plant characters in barley. J. Am. Soc. Agron. 29 : 754-760. 1937.
11. Tysdal, H. M. Influence of tripping, soil moisture, plant spacing and lodging on alfalfa seed production. A. Am. Soc. Agron. 38 : 515-535. 1946.
12. Welton, F. A., and V. H. Morris. Lodging in oats and wheat. Ohio Agr. Exp. Sta. Bull. 471. 1931.

CONTROL OF LOOSE SMUT OF BARLEY BY CHEMICAL AND PHYSICAL TREATMENTS[1]

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[Received for publication January 6, 1951]

The hot water method of treating wheat and barley seed infected with loose smut is effective, but it requires apparatus available on but few farms. Custom and community treating units are increasing in number, and these are performing a most useful service for a limited number of growers.

Since the loose smut fungus of barley and of wheat is embedded within the embryo, it is manifestly difficult to reach it with the chemicals commonly used for controlling the covered smuts, which are caused by surface-borne inoculum. However, it is possible that control of loose smut might be effected by a fungicidal chemical in solution, provided that the agent can penetrate the embryonic tissues without injury to the seed. Hanna and Popp (2) obtained partial control of loose smut in Reward wheat by soaking the seed in a solution of potassium iodide. Gassner and Kirchhoff (1) found that the addition of 1 per cent methyl alcohol to water used in the hot water treatment increased its effectiveness. Honecker (3) showed that the temperature of the water used in the hot water treatment for the control of loose smut in barley could be reduced to 45° C., provided that 0.1 per cent Ceresan was added.

Destruction of the embedded smut fungus hyphae should also be possible by physical agents other than heat. For example, the energy in high frequency sound waves might be applied to advantage in this connection.

In order to survey the practicability of using either chemical or physical methods for the control of loose smut, experiments were undertaken in which barley seed infected with the loose smut fungus was treated, prior to planting, with various chemical solutions and with supersonic vibrations. Data were secured on the incidence of loose smut in the resulting crop.

MATERIALS AND METHODS

During 1948 and 1949, preliminary experiments provided useful information on effective chemicals and indicated promising techniques for applying the treatments. In the spring of 1950, sufficient barley seed infected with loose smut fungus, *Ustilago nuda* (Jens.) Rostr., was secured to plant extensive field plots.

Chemical Treatments

In one set of tests, dry seed was soaked in water at room temperature (72°-75° F.) for six hours. It was then drained and placed in the chemical solutions. The seed remained in the solutions for 18, 22, or 27 hours. In another set of tests, the seed was immersed in water for 16 hours. After draining, it was spread out and covered with damp cloths until the swollen embryonic tissue had emerged from the seed coat. Emergence of from

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TABLE 1.—AVERAGE NUMBER OF HEALTHY AND SMUTTED PLANTS PER ROW OF MONTCALM BARLEY FROM SEED IMMERSED IN CHEMICAL SOLUTIONS FOR VARIOUS PERIODS BEFORE PLANTING

Treatment	Per cent	Duration of treatment in chemical solution									
		18 Hours.*		22 Hours*		27 Hours*		1 Hour†		4 Hours†	
		Healthy	Smutted	Healthy	Smutted	Healthy	Smutted	Healthy	Smutted	Healthy	Smutted
Oxyquinoline sulphate	0.1	7	0	12	0	1	0	85	3	63	3
Oxyquinoline sulphate	0.2	0	0	2	0	0	0	*85*	*2*	60	1
Boric acid	0.2	118	20	120	16	122	17	105	10	101	15
Boric acid	0.5	102	14	109	11	*95*	*5*	111	9	90	10
Salicylic acid	0.05	114	19	124	12	125	15	112	15	117	13
Salicylic acid	0.1	73	10	119	7	102	8	102	9	90	10
Spergon (tetracholoro-para-benzoquinone)	0.1	111	13	138	7	141	6	117	14	106	18
Spergon	0.2	135	17	129	9	*128*	*4*	92	20	109	12
Spergon	0.3	120	12	129	6	*138*	*4*	110	14	124	18
Actidione (from *Streptomyces griseus*)	0.002	123	13	130	20	133	12	106	13	114	12
Actidione	0.004	97	8	119	9	132	7	98	13	108	14
Bacterial culture	—	121	16	121	18	138	12	104	10	112	13
DN-4 (dinitro-o-cyclohexylphenol)	0.1	127	20	125	14	135	18	97	10	119	13
Arasan (tetramethyl-thiuram-disulphide)	0.1	124	16	129	18	149	16	127	17	120	16
Hexadow (benzene hexachloride)	0.05	130	16	131	21	148	14	104	14	138	18
Phygon (2,3-dichlor-1,4-naphthoquinone)	0.01	133	16	129	17	138	13	115	15	123	19
Bioquin (8-quinolinol)	0.01	122	16	113	14	139	16	134	15	108	16
Neotran (*bis-p*-chlorophenoxy-methane)	0.05	141	20	128	16	134	12	115	15	103	17
Fermate (ferric dimethyl-dithio-carbamate)	0.1	124	16	119	18	140	16	127	18	118	13
Iodine	0.04	126	14	116	16	136	17	111	16	119	12
Naphthaquinone	0.1	124	10	123	13	143	16	118	16	117	15
Na. 2,6-dichlorobenzenoneindophenol	0.1	97	18	128	12	121	19	112	19	115	15
Lithium iodide	0.1	120	13	125	13	128	14	115	16	118	15
Potassium iodide	2.0	93	4	79	2	*83*	*1*	*65*	*1*	32	0
Control (water treated seed)	—	121	17	120	14	123	19	113	15	108	16
Control (dry seed)		144 healthy, 22 smutted (average of 20 rows)									

* Seed presoaked 6 hours in water before chemical treatment. † Seed germinated before chemical treatment.

2 to 5 mm. was accomplished after 24 hours under the cloths in all except a few seeds. It was assumed that the unsprouted seeds were non-germinable. Following germination, the seed was immersed in the chemical solutions for from one to four hours before planting. To prevent sticking, fine, dry soil was mixed with the damp seed before placing it on the V-belt seeder. Plantings of approximately 200 seeds per row of chemically treated Montcalm barley were made during mid-May in Edmonton black loam soil in quadruplicate 12-foot rows. Controls were of two types, sprouted seed and dry seed. Total plants per row were counted a month after planting, and smutted plants were counted in mid-July.

On July 21 an additional planting of chemically treated seed was made. Only a portion of this planting survived the high temperatures and drought which prevailed immediately subsequent to planting. Counts of healthy and smutted plants were made on September 10.

Supersonic Tests

The seed used for the supersonic treatments was supplied by W. J. Cherewick, Dominion Laboratory of Plant Pathology, Winnipeg, Manitoba, and was approximately 40 per cent infected with loose smut as a result of vacuum inoculation. Treatments of the seed were made at the Department of Research and Development, Canadian National Railways, Montreal, Que., through the courtesy and co-operation of A. D. Macpherson, Controller of Tests and Materials Research, and A. T. G. Westbrook, Metallurgist. Seven 50-gram samples of barley seed were immersed in turn in 8 ounces of water for 16 hours in a steel container 2 inches wide, 2.5 inches long, and 6 inches deep. The energy of a 100-watt Hughes Supersonic Flaw Detector was then transmitted through the vessel and contents for various times and at 1.25 or 2.5 megacycles per second. Controls were untreated, dry seed. Data on the total number of plants produced from the treated seed were recorded during the late seedling stage and smut counts were made in mid-July.

RESULTS

Chemical Treatments

Sixteen chemicals were tested for possible efficiency in controlling loose smut. Of these, oxyquinoline sulphate, Spergon (tetrachloro-para-benzoquinone), boric acid, and salicylic acid had been shown to be effective in reducing loose smut in previous tests. Actidione, an antibiotic from *Streptomyces griseus*, and a bacterial culture isolated at this laboratory and known to possess strong antibiotic activity, were also included as test agents. Table 1 gives, for the first planting of the chemically treated seed, the names of the chemicals used and the respective data.

Control of loose smut in the non-germinated seed improved with increase in the period of immersion in the chemical solutions. The efficiency of a treatment was assessed by considering the degree of smut control in relation to reduction in stand of healthy plants. Thus, oxyquinoline sulphate, at the concentration used and for the periods of immersion employed, was unsatisfactory, since almost all seeds were killed. Boric acid 0.5 per cent, Spergon 0.1 per cent, 0.2 per cent, and 0.3 per cent,

and potassium iodide (2) 2 per cent effected good control of loose smut, but Spergon was considered the best chemical because it caused little mortality of healthy seed.

Smut was controlled satisfactorily in the germinated seed only by oxyquinoline sulphate and potassium iodide. Both chemicals reduced the stand seriously, but the former caused less reduction than did the latter. A period of immersion of one hour in the chemical solutions was as effective as an immersion of four hours.

Table 2 gives the data on the second planting (July 21) of treated barley. The period of immersion of this seed in chemical solutions was from 29 to 40 hours, following a 6-hour pre-soak in water. On September 10, as frost was imminent, all the plants in the rows were pulled. Detection of the smut-infected members was determined by cutting with a scalpel, longitudinally through the enfolded heads of the plants.

In the treatments summarized in Table 2, the efficiency of a 0.2 per cent solution of Spergon in controlling loose smut was outstanding. Only one plant of a total of 489 was smutted. The stand of healthy plants was 80 per cent of that of the controls grown from dry seed. A reduction of only 20 per cent in stand should be of minor significance in practice. Moreover, the fact that a 40-hour immersion in the Spergon solution had little deleterious effect upon the seed indicates the wide limits of safety in the use of this chemical. This quality should enhance the usefulness of the Spergon treatment in the hands of the farmer. Reduction in concentration of the potassium iodide and oxyquinoline sulphate solutions from those used in the first planting resulted in better stands, but also in less smut control. Immersion of the seed in water alone for a period of 46 hours caused a considerable reduction in both smutted and healthy plants. The activity of micro-organisms possibly responsible for this mortality is not a factor in the chemical solutions, as the chemicals are antiseptic.

Supersonic Treatments

The seed that had been treated with supersonic vibrations was planted in five randomized replicates in 12-foot rows, 200 seeds per row. Smut counts were made by pulling all plants and separating the healthy from the smutted ones. The data are given in Table 3.

The analysis of variance indicates that all treatments significantly reduced smut infection, and it is noteworthy that the treatment which effected the best control was that in which a frequency of 2.5 megacycles was employed and the water and seed in the container were agitated during the four minutes of treatment. Although it is obvious that loose smut was not reduced to an extent that would be of practical value, the experiment indicates that the supersonic treatment did appreciably reduce smut and that agitation during treatment enhanced its effects.

The analysis of variance of the data on healthy plants showed no significant differences for treatments. Therefore, the reduction in total stand was almost entirely attributable to mortality of the seed carrying loose smut mycelium in the embryo. Apparently the pathogen decreases the potential vigour of the seed which it invades. The germination of such seed is inhibited by chemical and physical treatments much more

TABLE 2.—EFFECT OF VARIOUS CHEMICAL SOLUTIONS ON THE CONTROL OF LOOSE SMUT IN MONTCALM BARLEY

Treatment	Pre-soak period (hr.)	Period in chemical solution (hr.)	Average number of plants per row	
			Healthy	Smutted
Potassium iodide 0.5 per cent	10	29	115	9.5
Oxyquinoline sulphate 0.05 per cent	6	40	115	9.5
Oxyquinoline sulphate 0.025 per cent	6	40	145	13.0
Spergon 0.2 per cent	6	40	122	0.2
Controls	40	—	120	12.2
Controls (dry seed)	—	—	153	24.0

TABLE 3.—INCIDENCE OF LOOSE SMUT IN BARLEY FROM SEED SUBJECTED TO VIBRATIONS FROM HUGHES SUPERSONIC FLAW DETECTOR (100 WATT) AT VARIOUS FREQUENCIES AND FOR VARIOUS TIMES

Vibration frequency meg./sec.	Time, min.	Pre-soak period (hr.)	Healthy plants (av.)	Smutted plants (av.)
1.25	6	16	105.0	57.8
2.5	1	16	107.6	55.6
2.5	2	16	114.6	59.8
2.5	4	16	113.8	61.6
2.5	6	16	114.2	59.8
2.5*	4	16	110.6	48.2
Control	—	—	105.4	82.0

* Seed and water agitated during treatment.

ANALYSIS OF VARIANCE

Smutted plants

Variation due to	D.F.	Sum of squares	Mean square	F.
Treatment	6	3235	539.2	5.78**
Replication	4	42	10.5	0.11
Error	24	2237	93.2	—

Necessary difference for significance—12.0.
** Significant at 1 per cent level.

Healthy plants

Variation due to	D.F.	Sum of squares	Mean square	F.
Treatment	6	526	87.7	0.64
Replication	4	988	247.0	1.80
Error	24	3299	137.5	—

Necessary difference for significance—14.76.

readily than is the germination of normal seed. Indeed, Wells and Platt (4) have shown that loose smut infection reduces the viability of barley even when no treatment is applied.

SUMMARY

Loose smut in Montcalm barley was 99.8 per cent eliminated by presoaking the seed for six hours in water and immersing it in a 0.2 per cent solution of Spergon (tetrachloro-para-benzoquinone) for 40 hours before planting. The stand of healthy plants was reduced 20 per cent. The results indicate that Spergon and possibly other chemicals may be of practical value in controlling loose smut.

Supersonic vibrations passed through a small steel tank containing barley in water significantly reduced loose smut in the crop from the seed.

ACKNOWLEDGMENTS

The author is deeply appreciative of the courtesy and co-operation of A. D. Macpherson, Controller of Tests and Materials Research, and A. T. G. Westbrook, Metallurgist, Department of Research and Development, Canadian National Railways, Montreal, in undertaking the supersonic treatments. The assistance of R. C. Russell and W. J. Cherewick, of the Dominion Laboratory of Plant Pathology at Saskatoon, Sask., and at Winnipeg, Man., respectively, and of F. Mehrer, Macnutt, Sask., in providing barley seed infected with loose smut, is gratefully acknowledged.

REFERENCES

1. Gassner, G., and H. Kirchhoff. Einige abschliessende Versuche über die Wirkung der Warmbenetzungsbeize. Phytopath. Z. 11 : 115-120. 1938. (Rev. Appl. Mycol. 17 : 667. 1938.)
2. Hanna, W. F., and W. Popp. Experiments on the control of loose smut of wheat by seed treatment. Proc. World's Grain Exhib. and Conf., Regina, Sask., 1933, 2 : 243-248. 1935.
3. Honecker, L. Erfahrungen und Beobachtungen über das Auftreten des Gerstenflugbrandes und über die Wirkung verschiedener Verfahren zu seiner Bekämpfung. Prakt. Bl Pfl Bau 19 : 186-201. 1941-42. (Rev. Appl. Mycol. 23 : 11. 1944.)
4. Wells, S. A., and A. W. Platt. The effect of loose smut on the viability of artificially inoculated barley seeds. Sci. Agr. 29 : 45-52. 1949.

A STUDY OF SOME SEED-BORNE DISEASES OF CEREALS IN CANADA

II. KINDS OF FUNGI AND PREVALENCE OF DISEASE IN CEREAL SEED[1]

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[Received for publication December 21, 1950]

INTRODUCTION

In Part I of this investigation (4), different methods of testing cereal seed for seed-borne diseases were described, compared, and discussed. Part II is concerned chiefly with defects in such seed. The data presented here were obtained by a seed-testing technique earlier found to be one of the most suitable.

Though the principal object of the present investigation was to determine the prevalence of defects in seed, a subordinate one was to discover whether or not there are any areas in Canada consistently producing seed free, or comparatively free, from disease. It was hoped also that sources of diseased seed and of very clean seed could be obtained for use in subsequent field experiments.

The survey data dealing with the occurrence of fungi within the seed was derived from plating tests carried on each year during the five-year period 1939-43. The remaining survey data, concerned with other defects of seed, were obtained either from non-sterile soil tests designed to show seed germination and seedling lesions, or from centrifuge tests for smut. The two latter tests were conducted over the seven-year period 1939-1945. In all, 8428 samples of seed were studied, but only 6204 of them were subjected to a plating test for fungi. All the testing discussed here was performed at the Dominion Laboratory of Plant Pathology, Winnipeg.

EXPERIMENTAL PROCEDURE

The seed tested in this investigation was obtained from a number of different sources. Samples of Foundation and Elite seed were collected each year through the agency of the Canadian Seed Growers' Association, and samples of Registered and Certified seed were furnished by various seed-testing laboratories of the Production Service, Canada Department of Agriculture. The Commercial seed used in the tests was obtained from the laboratories just mentioned, from reference lots held on file at the Grain Inspection Office (Western Division) of the Board of Grain Commissioners at Winnipeg, and from stocks held in farmers' seed-bins. The number of samples in each of the different seed grades tested each year is shown in Table 1. The number obtained each year from the different Canadian seed-inspection districts is shown in Table 2.

Upon reaching the testing laboratory at Winnipeg, each seed sample was given an accession number and its principal characteristics and origin were recorded. Some of the seed was then poured on to a clean sheet of paper and 100-kernel lots were counted, one for the plating test and two for

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TABLE 1.—NUMBER AND GRADE OF SAMPLES OF WHEAT, OATS, AND BARLEY SEED TESTED DURING THE PERIOD 1939-45

Crop	Year	Grade					Total
		Foundation	Elite	Registered	Certified	Commercial	
Wheat	1939	0	0	16	23	1442	1481
	1940	1	14	80	1	378	474
	1941	6	13	5	42	544	610
	1942	14	51	74	7	255	401
	1943	12	61	44	2	111	230
	1944	25	70	40	4	95	234
	1945	15	86	56	1	61	219
	Total	73	295	315	80	2886	3649
Oats	1939	0	0	9	28	332	369
	1940	0	24	494	0	132	650
	1941	7	20	47	15	396	485
	1942	6	59	80	13	247	405
	1943	12	69	21	2	171	275
	1944	10	65	40	3	150	268
	1945	11	64	34	2	151	262
	Total	46	301	725	63	1579	2714
Barley	1939	0	0	3	2	193	198
	1940	2	11	188	0	219	420
	1941	2	18	20	37	373	450
	1942	8	32	52	16	262	370
	1943	11	35	19	7	147	219
	1944	9	22	42	10	119	202
	1945	9	34	28	9	126	206
	Total	41	152	352	81	1439	2065
Total		160	748	1392	224	5899	8428

the non-sterile soil test. A new sheet for each subsequent sample was used to avoid the transfer of seed contaminants. Finally, a 40-gram lot of seed was taken from each sample for the smut test.

In the determination of the internal fungus flora of seed (plating test), one of the 100-kernel lots from each sample was surface-sterilized by immersion in a mixture of mercuric chloride and alcohol (1 part of 95 per cent ethyl alcohol in 3 parts of a 0.1 per cent aqueous solution of mercuric chloride) and then plated on warm potato-sucrose agar previously acidified to pH 4.6 with 5 per cent lactic acid. The period of immersion in the alcohol-mercuric chloride mixture was 4 minutes for wheat, 2 minutes for oats, and 5 minutes for barley; and, after surface sterilization, the treated seed was rinsed in three changes of sterile water. Ten seeds were put in each Petri dish. The dishes with the seeded agar plates were then stored for one week in a chamber held at 24°-26° C. At the end of this time, the plates were examined for fungus and bacterial colonies and the numbers and kinds of fungi were recorded. With practice, most of the fungus colonies occurring on the plates could be identified macroscopically, and only a comparatively small number required sub-culturing and microscopic examination.

TABLE 2.—NUMBER OF SAMPLES RECEIVED EACH YEAR FROM EACH OF EIGHT CANADIAN SEED INSPECTION DISTRICTS DURING THE PERIOD 1939-45

Crop	Year	Seed inspection district[1]								Total
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Wheat	1939	14	0	57	0	389	574	442	5	1481
	1940	1	3	11	16	443	0	0	0	474
	1941	24	17	31	26	431	30	30	21	610
	1942	25	15	32	25	201	49	38	16	401
	1943	17	10	35	25	43	54	34	12	230
	1944	21	13	46	2	40	57	38	17	234
	1945	14	9	29	2	44	56	46	19	219
	Total	116	67	241	96	1591	820	628	90	3649
Oats	1939	62	41	0	0	89	0	150	27	369
	1940	19	29	195	237	170	0	0	0	650
	1941	29	32	32	29	272	30	30	31	485
	1942	31	28	34	25	179	46	37	25	405
	1943	23	34	37	25	46	48	38	24	275
	1944	26	34	32	25	38	49	36	28	268
	1945	29	31	32	25	25	51	41	28	262
	Total	219	229	362	366	819	224	332	163	2714
Barley	1939	29	1	2	0	141	0	23	2	198
	1940	4	15	64	76	261	0	0	0	420
	1941	22	29	28	29	269	30	30	13	450
	1942	26	27	33	25	179	36	33	11	370
	1943	19	17	33	25	46	36	32	11	219
	1944	26	19	32	25	20	34	36	10	202
	1945	18	30	30	25	22	31	36	14	206
	Total	144	138	222	205	938	167	190	61	2065
Total		479	434	825	667	3348	1211	1150	314	8428

[1] (1) Maritime Provinces, (2) Quebec, (3) Northern Ontario, (4) Southern Ontario, (5) Manitoba and Western Ontario, (6) Saskatchewan, (7) Alberta, (8) British Columbia.

The two other 100-kernel lots of seed from each sample were sown (one lot treated with diluted New Improved Ceresan and one lot left untreated) in adjacent rows in a greenhouse bed of non-sterile soil prepared by the method described earlier (3). After ten days at 18°-20° C., the seedlings from the treated and the untreated seed were compared with respect to their number, vigour, and freedom from leaf and coleoptile lesions, and these data were used as indices of the health condition of the sample. When the data were used in a formula (3), the result showed the treatment required for each lot of seed. In all cases, the application of the formula was considered in relation to the practicability of the recommendation. For instance, the use of better seed was considered to be preferable to a very large increase in rate of seeding.

The 40-gram lot taken from each sample was used for a determination of the smut spore-load on the seed, according to the method described by Cherewick (1). The procedure consists essentially of adding an aqueous solution of a wetting agent (an ester of sulphonated bicarboxylic acid) to the seed, shaking the mixture, and then decanting and centrifuging the

suspension obtained. The sediment, after dilution with a solution of gelatine, is then examined under a microscope and the amount of smut spores present determined.

Spore-load determinations were made for the following smut fungi: on wheat seed, *Tilletia foetida* (Wallr.) Liro and *T. caries* (D.C.) Tul.; on oat seed, *Ustilago Avenae* (Pers.) Rostr. and *U. Kolleri* Wille; and on barley seed, *Ustilago nigra* Tapke and *U. Hordei* (Pers.) Lagh.

No attempt was made to examine wheat and barley seed for the presence of their respective loose smut fungi, *Ustilago Tritici* (Pers.) Rostr. and *U. nuda* Kell. & Swing.

In testing barley seed, it was found impossible, by the non-sterile soil test, to determine accurately the percentage of seeds infected or contaminated with *Helminthosporium teres* Sacc. The amount of internal infection was, however, disclosed when the seed was surface-sterilized and plated on agar. Determinations of the percentage of seeds infected with *H. teres* were made by this method during the period 1939-43, but, in the subsequent two years (1944-1945), the method used was as follows: Untreated barley seed was incubated on moistened, thick (No. 3) filter paper in Petri dishes (ten seeds to a dish) for four days at about 26° C. At the end of the incubation period, the seeds were examined individually under a low-power binocular microscope for the presence of the characteristic fructifications of *H. teres*.

For purposes of this investigation, a seed lot was considered to be healthy if 90 per cent or more of the seeds were uninfected, producing healthy unblemished seedlings; and if, in addition, it carried less than a specified amount of smut spores (1 part of smut spores by weight to 128,000 parts of seed in the 1939-1941 samples, and 1 : 1,000,000 for wheat and 1 : 1,500,000 for oats and barley in the 1942-1945 samples). The change to a lower tolerance of smut was made in 1942 after it was found that too much smut appeared in the crops from seed with the higher spore load. All other seed samples were considered to require seed disinfection, an increase in rate of seeding, or both.

EXPERIMENTAL RESULTS

Internal Microflora of Cereal Seed

One of the most striking characteristics of the microflora of the seed was the ubiquity of *Alternaria* and the frequency of its occurrence in the samples, as compared with other fungi. In contrast, fungi of the genus *Helminthosporium* were comparatively rare, except in a few heavily infected samples from particular areas. By and large, oat and barley seed showed a more abundant and varied flora than did wheat seed.

In all three crops, seed from Alberta and Saskatchewan was less frequently infected with fungi than was the seed from the other provinces. Seed from the Maritime Provinces showed the most severe infection. Of passing interest is the fact that, on a number of occasions, coprophilous fungi, such as *Sordaria fimicola* (Rob.) Ces. & de Not. and *Gelasinospora tetrasperma* Dowding, were isolated from surface-sterilized seed.

Forty-three genera and 102 species of fungi were recognized among the isolates obtained from the seed. The relative prevalence of these genera (and of a few pathogenic species) in Canadian wheat, oat, and barley seed is shown in Table 3. In Table 4 is shown the prevalence of

TABLE 3.—COMPARATIVE ABUNDANCE OF SEED-BORNE MICRO-ORGANISMS IN SURFACE-STERILIZED SEED OF WHEAT, OATS, AND BARLEY PRODUCED IN CANADA (SUMMARY OF TESTS ON 6204 SAMPLES)

Micro-organism	Mean percentage of seeds infected		
	Wheat	Oats	Barley
Absidia	Tr.[1]	0.14	0.08
Acremoniella	Tr.	0.06	Tr.
Alternaria	55.14	55.76	66.51
Aspergillus	0.06	0.21	0.10
Bacteria	1.22	0.98	1.84
Basidiomycetes	Tr.	Tr.	0.01
Botrytis	0.03	0.04	0.02
Camarosporium	Tr.	Tr.	Tr.
Candida	0.00	Tr.	0.02
Cephalosporium	Tr.	Tr.	Tr.
Cephalothecium	0.02	0.26	0.05
Chaetomium	0.05	0.16	0.09
Circinella	Tr.	0.00	Tr.
Cladosporium	0.30	2.53	1.51
Colletotrichum	0.00	Tr.	Tr.
Constantinella	Tr.	0.00	Tr.
Curvularia	0.06	0.09	0.10
Delitschia	Tr.	0.00	0.00
Epicoccum	0.51	0.74	0.96
Fusarium	0.65	3.28	1.98
Gonatobotrys	Tr.	0.00	0.00
Gelasinospora	0.00	0.00	Tr.
Helminthosporium			
H. sativum	2.45	1.41	5.64
H. teres	0.09	Tr.	3.18
H. Avenae	Tr.	3.25	Tr.
H. spp.	0.21	0.31	0.14
Macrophomina	0.00	0.00	Tr.
Monilia	0.00	Tr.	Tr.
Monotospora	Tr.	0.00	0.00
Mucor	0.03	0.23	0.07
Nigrospora	0.80	1.37	0.93
Paecilomyces	0.00	Tr.	Tr.
Papularia	0.01	0.06	0.01
Penicillium	0.21	0.32	0.48
Phoma	0.02	0.02	0.02
Pullularia	0.56	2.32	2.00
Pythium	0.00	Tr.	Tr.
Rhizoctonia	Tr.	Tr.	Tr.
Rhizopus	0.02	0.14	0.08
Sclerotinia	Tr.	Tr.	Tr.
Sclerotium	Tr.	0.00	Tr.
Scopulariopsis	Tr.	Tr.	0.00
Septoria	0.70	0.08	0.42
Sordaria	Tr.	0.05	0.04
Stemphylium	0.02	0.03	0.04
Torula	0.02	0.03	0.04
Trichoderma	0.01	0.07	0.02
Verticillium	0.00	0.06	0.00
Yeasts	Tr.	Tr.	Tr.
Unknown	0.07	0.07	0.11

[1] Tr. = Less than 0.01 per cent of seeds infected.

TABLE 4.—COMPARATIVE ABUNDANCE OF SOME OF THE MORE COMMON FUNGI FOUND IN SURFACE-STERILIZED SEED FROM DIFFERENT SEED-INSPECTION DISTRICTS OF CANADA

Crop	Inspection district[1]	Mean percentage of seeds infected							
		Alternaria	*Hel. sativum*	*Hel. teres*	*Hel. Avenae*	*Fusarium*	*Cladosporium*	*Pullularia*	*Nigrospora*
Wheat	1	43.25	2.00	0.13	0.01	2.20	1.32	4.39	0.04
	2	54.60	1.56	0.12	0.00	3.70	0.86	3.36	0.06
	3	52.82	5.94	0.03	0.00	2.00	0.52	1.73	0.26
	4	44.56	0.84	0.02	0.01	0.23	0.09	0.64	0.43
	5	68.68	3.62	0.11	Tr.	0.72	0.10	0.19	1.46
	6	29.18	0.78	0.07	0.00	0.13	0.15	0.26	0.05
	7	13.50	0.32	0.05	0.00	0.14	0.91	0.35	0.05
	8	19.56	0.33	0.00	0.00	0.30	0.76	2.01	0.00
Oats	1	47.18	0.40	0.00	9.36	6.21	6.90	5.19	Tr.
	2	59.77	0.48	0.00	8.51	8.42	2.82	2.65	0.19
	3	60.55	1.06	0.00	5.93	5.79	3.06	2.77	0.33
	4	61.98	1.03	0.00	8.82	4.18	1.39	3.25	0.83
	5	66.76	2.51	Tr.[2]	0.94	2.13	0.56	1.10	2.76
	6	41.14	0.69	0.00	1.22	0.73	2.39	1.96	1.01
	7	23.62	0.38	0.00	1.06	0.71	3.90	1.86	0.21
	8	19.27	0.01	0.00	2.91	0.89	11.57	5.62	0.04
Barley	1	55.02	23.03	3.31	0.00	4.96	3.09	5.80	0.02
	2	74.16	6.30	5.00	0.00	7.22	1.24	3.51	0.16
	3	73.50	7.94	1.65	0.00	3.26	0.80	6.38	0.16
	4	79.52	7.00	7.68	0.00	1.85	0.29	1.69	0.23
	5	75.65	4.99	2.90	Tr.	1.38	0.47	0.87	1.52
	6	55.79	2.06	3.29	0.00	0.58	1.76	0.98	0.79
	7	30.50	0.46	1.18	0.00	0.79	5.98	1.08	0.31
	8	22.14	0.21	0.60	0.00	0.35	4.83	5.51	1.12

[1] For district names, see footnote under Table 2.
[2] Tr. = Less than 0.01 per cent.

certain dominant genera and species in each of the eight official seed-inspection districts of Canada. Some fungus isolates failed to fruit in culture and could not be identified, except that, in a few instances, clamp-connections indicated that they were Basidiomycetes. No attempt was made to identify bacteria and yeasts. The comparative prevalence of these unknowns in the three crops is shown in Table 3 also.

Since detailed tabulation of all the data obtained from the plating-out tests referred to in this paper would occupy too much space, the salient facts regarding the micro-organisms observed in cereal seed are brought out in the following brief discussions of the genera encountered.

Absidia

Isolates of this genus were recovered comparatively rarely, mostly from oats and barley, and more or less uniformly from all the seed inspection districts of Canada. Only two species, *A. orchidis* (Vuill.) Hagem and *A. glauca* Hagem were isolated, neither of which was found to be pathogenic to cereals.

Acremoniella

Only one species, *A. atra* (Cda.) Sacc., was detected. It appeared most frequently in oat seed from Eastern Canada, and seemed to be intimately associated with *Alternaria*. It did not appear to parasitize cereal seedlings.

Alternaria

This genus was very abundantly represented in all seed inspection districts on all three crops. Several cultural types were observed, all possessing short-beaked, faintly or coarsely verrucose brown spores with usually three transverse and several longitudinal

septa. Spores were variable in size, but usually 20-35 × 10-12 μ. The isolates tested appeared to be weakly pathogenic to seedlings, particularly to those of wheat grown in agar plate culture. All cultural types appeared to belong to the group species *A. tenuis* sensu Wiltshire.

Aspergillus

Fungi belonging to this genus were isolated more frequently from oats than from barley or wheat, and were closely associated with extreme mouldiness of the seed. Mouldy seed was received more frequently from Eastern Canada and Manitoba than from farther west. *A. glaucus* Link and *A. flavus* Link were found most often. *A. flavipes* Bainier & Sartory, *A. niger* Van Tiegh., and *A. ruber* (Spieckermann & Bremer) T. & C. were isolated very seldom. *A. minutus* Abbott was isolated only once—from oats.

Basidiomycetes

Slow-growing, colourless colonies of fungi with clamp-connections were isolated rarely from all three crops. Their occurrence in seed was probably the result of the seed having had contact with soil. They were recovered from samples that originated in Ontario, Manitoba, and Saskatchewan. No tests of pathogenicity were made.

Bacteria

Colonies of bacteria were frequently found arising from surface-sterilized seed, their incidence being higher in barley than in wheat or oats and higher in seed from Eastern Canada and Manitoba than from the more western provinces. The colony colour was usually white or yellow, but no attempt was made to identify the species represented.

Botrytis

Only one species, *B. cinerea* Pers., was observed. It occurred but rarely, slightly more often in oats than in wheat and barley, and with practically no difference between seed-inspection districts in the percentage of seeds infected.

Camarosporium

Only one species, apparently *C. umbonatum* Brenckle, was recovered. Pycnidiospores 5-7 × 12-17 μ. It was isolated very rarely and only from seed from Manitoba and Saskatchewan.

Candida

This yeast-like genus of fungi occurred only in oats and barley from the Prairie Provinces. The variable species *C. variabilis* (Lind.) Berk. seemed to be the only one present.

Cephalosporium

This genus occurred in trace amounts in all three crops, but was not confined to any particular area. Only one species, referred to *C. curtipes* Sacc., was recovered.

Cephalothecium

The single species isolated, *C. roseum* Corda, was obtained mostly from oats. It occurred in seed from all seed inspection districts but mostly in the seed samples from Eastern Canada. It caused some browning of seedling coleoptiles on agar plates.

Chaetomium

Fungi belonging to this genus were found to be more abundant in oat seed than in wheat and barley seed. The species isolated, *C. funicola* Cooke, *C. flexuosum* Palliser, and one species not identified but placed near *C. murorum*, occurred infrequently in seed from all areas.

Circinella

A single species, *C. aspera* Lendner, occurred in trace amounts in wheat seed from Alberta. It appeared to be merely a chance associate of the seed, with no pathologic significance.

Cladosporium

It was impossible to examine closely all the isolates of this genus obtained from cereal seed, but all appeared to fall within the extremely variable species *C. herbarum* (Pers.) Link. Most abundant in oats and barley, the fungus occurred frequently in seed from all areas of Canada. It most cases, it was associated with some seed discoloration. Both smooth-spored and rough-spored forms were observed.

Colletotrichum

An unidentified species occurred rarely in oats and barley from the Prairie Provinces. It was probably a chance associate of the seed.

Constantinella

An unidentified fungus, tentatively assigned to this genus by Dr. G. R. Bisby of the Commonwealth Mycological Institute at Kew, was isolated several times from wheat seed originating in Saskatchewan and Alberta, and once from barley seed from Alberta. Conidiophores were irregularly penicillate, and the spores were catenulate, smooth, moderately thick-walled, obovate, 4 × 7 μ.

Curvularia

Two species, *C. geniculata* (Tr. & E.) Boedijn and *C. spicifera* (Bainier) Boedijn, particularly the former, appeared regularly in the seed of all three crops. In plating tests with the seed, the presence of either fungus resulted in a browning of the coleoptile, thus indicating a certain degree of pathogenicity. It is worthy of note that the spores of *C. spicifera* are not typical of the genus, but resemble those of a short-spored *Helminthosporium*. In this instance, the original specific name (*Brachycladium spiciferum* Bainier), amended by Boedijn, apparently needs further amendment.

Delitschia

One culture of an undetermined species was obtained from Manitoba-grown wheat seed. Ascospores were brown, oval, uniseptate or occasionally continuous, averaging 28 × 16 μ. The two cells of each ascospore differed greatly in size, the basal one being much smaller than the apical one and usually almost colourless.

Epicoccum

Only one species, *E. purpurascens* Ehrenberg, was found, but it occurred frequently in wheat, oats, and barley seed from all areas in Canada. The presence of the fungus did not appear to injure the seed. Spores were globose, muriform, coarsely verrucose, dark brown, often with a short persistent stipe, 18-22 μ in diameter.

Fusarium

Fungi of this genus occurred comparatively abundantly in seed of oats and barley, and somewhat less in wheat. At least 18 different species, varieties, or forms (identified by Dr. W. L. Gordon, Dominion Laboratory of Plant Pathology, Winnipeg), were present. These have been listed elsewhere (2). *F. Poae* (Pk.) Wr., *F. Equiseti* (Cda.) Sacc., and *F. Scirpi* var. *acuminatum* (Ell. & Ev.) Wr. were the predominant species. The species commonly associated with cereal root rots, *F. culmorum* (W. G. Sm.) Sacc. and *F. graminearum* Sch., were isolated relatively seldom.

Gelasinospora

This curious, usually coprophilous, member of the Pyrenomycetes was isolated on only two occasions, both times from barley seed originating in Manitoba. It showed no pathogenic effects on the seedlings. Only one species, *G. tetrasperma* Dowding, was represented.

Gonatobotrys

One species, identified as *G. simplex* Cda., was isolated in trace amounts from Manitoba wheat. Spores hyaline, obovate, 14 × 7 μ.

Helminthosporium

At least six species of this genus were observed, namely, *H. sativum* P. K. & B., *H. teres* Sacc., *H. Avenae* Eidam, *H. gramineum* Rabenhorst, *H. tetramera* McKinney, and a species placed near *H. bicolor* Mitra or *H. halodes* Drechsler. All these species, except *H. gramineum* (which was found only in barley), were isolated from each of the three cereals surveyed. *H. sativum* occurred chiefly in barley and wheat, *H. teres* chiefly in barley, and *H. Avenae* chiefly in oats. The other species occurred comparatively infrequently. Most of the heavly infected seed samples originated in the Maritime Provinces, Quebec, and Manitoba.

Macrophomina

M. Phaseoli (Maubl.) Ashby was isolated in trace amounts from wheat grown in southern Ontario.

Monilia

Trace amounts of *M. sitophila* (Mont.) Sacc. occurred in oats and barley seed from Ontario.

Monotospora

A single species (with several variants), *M. Daleae* Mason, occurred rarely in wheat seed from Alberta.

Mucor

Fungi belonging to this genus were found in seed from all seed inspection districts, slightly more often in oats than in wheat and barley. *M. sphaerosporus* Hagem, *M. sylvaticus* Hagem, *M. ramanianus* A. Moeller, *M.* (?) *christianiensis* Hagem, *M. spinescens* Lendner, and *M.* (?) *Jansseni* Lendner were the species among which the various isolates were distributed.

Nigrospora

Only one species, *N. sphaerica* (Sacc.) Mason, was observed. It was relatively abundant in all three crops. Although occurring in all the seed inspection districts, it was particularly prevalent in Manitoba during 1940 and 1941, when excessively wet weather delayed threshing of swathed grain. Spores subglobose, almost black, smooth, about 15 μ in diameter.

Paecilomyces

Trace infections of oats and barley seed by *P. varioti* Bainier were found in seed samples originating in Western Canada.

Papularia

One species, *P. sphaerosperma* (Pers.) v. Höhn., occurred in small amounts in all three crops, but slightly more often in seed samples from Eastern Canada than in those from Western Canada. Spores brown, with paler equatorial zone, lenticular, 6-7 μ in diameter.

Penicillium

Seed infected by *Penicillium* spp. was received from all seed inspection districts. In most samples the percentage of seeds infected was low, with little adverse effect on seed germination, but, in the few samples more severely attacked, germination was much reduced. Barley and oats appeared to be more subject than wheat to infection. The species encountered included *P. albidum* Sopp, *P. Urticae* Bainier, *P. citrinum* Thom, *P. matris-meae* Zaleski, *P. frequentans* Westling, *P. glauco-roseum* Demelius, *P. tardum* (Bainier) Thom, *P. Thomii* Maire, *P. rugulosum* Thom, *P. chrysogenum* Thom, *P. canescens* Sopp, *P. Steckii* Zaleski, *P. columnare* Thom, *P. obscurum* Biourge, *P. janthinellum* Biourge, *P. Jenseni* Zaleski, *P. granulatum* Bainier, *P. cyano-fulvum* Biourge, *P. hirsutum* B. & S., *P. Kapuscinskii* Zaleski, *P. flavi-dorsum* Biourge, *P. sanguineum* Sopp, *P. notatum* Westling, *P. expansum* Link emend. Thom, *P. purpurogenum* Stoll, and *P. citreo-nigrum* Dierckx.

Phoma

At least three species of *Phoma* were isolated from wheat, oat, and barley seed in trace amounts. *P. glomerata* Wr. and Hoch. was the most common. The other two species, one with spores 6-7 $\times$ 3 μ and the other with spores 4 $\times$ 2 μ, were not identified. Isolates were obtained from all seed-inspection districts.

Pullularia

These yeast-like fungi were comparatively abundant in oats and barley and to a lesser extent in wheat seed from all seed inspection districts. Several cultural types were isolated, but they all appeared to be variants of one species, *P. pullulans* (DeBary & Löw) Berk.

Pythium

A species, not determined but with spherical sporangia, 10-12 μ in diameter, and with smooth-surface oospores, 25-27 μ in diameter, was isolated in trace amounts from Manitoba barley and oats. Infection of the seed presumably resulted from contact with soil.

Rhizoctonia

R. solani Kühn (*Pellicularia filamentosa* (Pat.) Rogers) was isolated from the seed of all three crops in trace amounts. Most of the isolates were obtained from Ontario and Manitoba seed, but a few were from Quebec seed.

Rhizopus

Representatives of this genus appeared to be a common inhabitant of wheat seed from Western Canada and of oat and barley seed from it and other parts of Canada. The following species were observed: *R. nigricans* Ehrenberg, *R. elegans* Eidam, *R. arrhizus* Fischer, and *R. Tritici* Saito.

Sclerotinia

A fungus identified as *S. sclerotiorum* (Lib.) Mass., appeared in trace amounts in wheat, oat, and barley seed from Manitoba, and in one lot of barley seed from Quebec.

Sclerotium

A fungus with subspherical or irregular red-brown sclerotia, considered to be *S. Delphinii* Welch, was isolated occasionally from wheat and barley seed from Manitoba.

Scopulariopsis

S. brevicaulis (Sacc.) Bainier was found in trace amounts in wheat and oat seed from southern Ontario and in oat seed from Manitoba and Alberta.

Septoria

Two species were recognized and both occurred rather frequently in wheat, oat, and barley seed. In Eastern Canada, wheat was the crop most heavily infected and *S. nodorum* Berk. predominated; in Western Canada, barley was the crop most heavily infected and *S. Avenae* Frank f. sp. *triticea* Johnson predominated.

Sordaria

One species of this coprophilous genus, *S. fimicola* (Rob.) Ces. & de Not., was recovered from a considerable number of seed samples of oats and barley, but comparatively rarely from wheat. It appeared in seed from all seed inspection districts. Possibly this fungus, as well as *Delitschia* sp. and *Gelasinospora tetrasperma*, did not actually invade the seed but merely escaped surface-sterilization.

Stemphylium

Fungi of this genus were not uncommon in wheat, oat, and barley seed, particularly in samples from Western Canada. The isolates obtained could be separated into two groups, both with very dark, rough, almost sarcinaeform spores. In one group, the spores were approximately 23-27 μ in diameter, and were coarsely verrucose; in the other, they were 28-33 μ in diameter and echinulate. It is probable that both types should be included in the variable species *S. botryosum* Wallr.

Torula

Only one species, referred to *T. antennata* Pers., occurred in the samples of cereal seed examined. A small percentage of infected seed was found in all three crops. Infection was more prevalent in seed from Western than from Eastern Canada. Fructifications of the fungus were very reminiscent of *Hormodendron*, but the spores were elongate, 8-17 $\times$ 2-4 μ.

Trichoderma

Members of this genus were found in all three crops, but chiefly in oats. The percentage of kernels infected was always small. Three species, *T. glaucum* Abbott, *T. Koningi* Oud., and *T. viride* Pers. *ex* Fries, were recognized, the last being the most common.

Verticillium

A fungus answering the general description of *Cephalosporium acremonium* Cda. was recovered in large amounts from oat seed produced in eastern Ontario in 1941. It had branching conidiophores and was therefore assigned to the genus *Verticillium*.

Yeasts

These fungi, both white and pink, occurred in seed of all three crops, but less than 0.01 per cent of the kernels were involved. Their presence was thought to be of no special significance.

Unknown Fungi

A considerable number of fungi isolated from cereal seed were not identified, chiefly for the reason that they failed to sporulate. A few of those that did produce spores were tentatively placed in the genera *Mesobotrys*, *Papulaspora*, *Acremonium*, *Rhopalomyces*, *Gloeosporium*, *Volutella*, and *Ramularia*.

General Health Condition of Canadian Cereal Seed

In the section of this paper dealing with experimental procedure, a definition was given for "healthy" or sound seed. For purposes of this investigation and further discussion, it may be mentioned that seed was considered to be unhealthy or unsound if it was weak or low in germination; was damaged mechanically or by frost; was infected by various seedling-blight, leaf-spot, or mould fungi; or was contaminated with smut spores to a degree above the tolerance allowed for healthy seed. As already explained, most of the seed defects just mentioned could be detected by the combined non-sterile soil and centrifuge tests.

TABLE 5.—PERCENTAGE OF UNSOUND SAMPLES OF SEED OCCURRING IN DIFFERENT YEARS IN THE EIGHT SEED-INSPECTION DISTRICTS OF CANADA

Crop	Year	Seed inspection district[1]							
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Wheat	1939	64.0	N.S.[2]	35.0	N.S.	43.0	13.0	18.0	60.0
	1940	100.0	33.0	27.0	25.0	51.0	N.S.	N.S.	N.S.
	1941	92.0	41.0	80.0	54.0	60.0	43.0	60.0	24.0
	1942	72.0	53.0	53.0	76.0	59.0	47.0	34.0	31.0
	1943	94.0	80.0	88.0	80.0	56.0	37.0	76.0	67.0
	1944	67.0	69.0	69.0	50.0	80.0	44.0	42.0	65.0
	1945	57.0	56.0	55.0	100.0	66.0	12.0	28.0	47.0
	Mean	76.0	57.0	60.0	63.0	54.0	20.0	26.0	45.0
Oats	1939	90.0	92.0	N.S.	N.S.	46.0	N.S.	28.0	21.0
	1940	63.0	86.0	60.0	74.0	41.0	N.S.	N.S.	N.S.
	1941	96.0	31.0	44.0	58.0	91.0	96.0	90.0	68.0
	1942	83.0	75.0	73.0	88.0	67.0	50.0	51.0	52.0
	1943	82.0	79.0	76.0	76.0	43.0	79.0	89.0	50.0
	1944	81.0	65.0	87.0	56.0	34.0	33.0	42.0	43.0
	1945	83.0	87.0	69.0	64.0	44.0	53.0	54.0	75.0
	Mean	85.0	72.0	65.0	72.0	64.0	59.0	48.0	56.0
Barley	1939	86.0	100.0	0.0	N.S.	15.0	N.S.	26.0	0.0
	1940	25.0	13.0	50.0	50.0	15.0	N.S.	N.S.	N.S.
	1941	77.0	51.0	29.0	21.0	85.0	97.0	27.0	23.0
	1942	69.0	85.0	51.0	36.0	74.0	44.0	18.0	46.0
	1943	94.0	94.0	85.0	52.0	67.0	53.0	41.0	36.0
	1944	62.0	63.0	56.0	36.0	65.0	29.0	28.0	40.0
	1945	72.0	96.0	83.0	40.0	36.0	42.0	29.0	78.0
	Mean	75.0	71.0	58.0	41.0	50.0	52.0	30.0	52.0
Mean		79.6	69.2	61.2	61.3	55.8	31.9	32.9	52.3

[1] For district names, see footnote under Table 2.
[2] N.S. = No samples.

In Table 5 are shown the percentages of unsound samples of wheat, oats, and barley originating from the different seed inspection districts of Canada. The data presented show a decided general tendency for seed from Eastern Canada to be less healthy than that from Western Canada. This tendency would be even more pronounced if only the infection by seedling-blight, leaf-spot, and mould fungi were considered, since much of the eastern seed was heavily infected by these organisms. In Western Canada, however, the amount of mechanical and frost injury to seed was considerably greater than in Eastern Canada and, since this injury also decreased germination, it tended to diminish the difference between the percentages of unsound samples from the two areas. The amount of smut in the different crops was, in general, fairly uniform for all areas.

Owing possibly to variations in weather conditions from year to year and from place to place, the percentage of seed infected and the amount of injury varied considerably in different districts. An example of this variation is given in Table 6, which shows for wheat and barley the average percentage of kernels infected by *Helminthosporium sativum* in different districts in consecutive years. In a similar way, weather conditions

TABLE 6.—VARIATION IN THE PERCENTAGE OF WHEAT AND BARLEY SEEDS INFECTED WITH *Helminthosporium sativum* IN DIFFERENT DISTRICTS AND IN DIFFERENT YEARS

Crop	Seed inspection district[1]	1939	1940	1941	1942	1943
Wheat	1	5.5	0.0	0.8	1.1	1.0
	2	Tr.	Tr.	Tr.	0.0	7.2
	3	2.7	2.8	5.6	1.3	12.0
	4	0.5	Tr.[2]	1.8	0.4	0.8
	5	2.0	2.3	5.5	4.9	4.5
	6	0.4	N.S.[3]	1.6	3.4	0.9
	7	Tr.	N.S.	1.4	0.7	0.9
	8	0.0	N.S.	0.8	0.0	0.0
Barley	1	48.8	11.7	17.4	15.8	22.6
	2	11.1	0.7	4.1	1.8	15.6
	3	Tr.	4.3	5.2	7.7	17.0
	4	3.3	6.1	2.9	8.9	17.2
	5	3.5	3.4	7.7	4.9	6.3
	6	0.2	N.S.	3.6	3.3	0.9
	7	Tr.	N.S.	2.2	0.3	0.2
	8	Tr.	N.S.	0.1	Tr.	0.0

[1] For seed inspection district names, see footnote under Table 2.
[2] Less than 0.1 per cent.
[3] No samples.

appeared to affect the amount of other defects. For example, damp weather increased the amount of mouldiness in harvested or threshed grain, excessively dry weather during threshing increased the amount of mechanical injury from threshing, and so forth.

When the seed samples tested during this study were grouped according to seed grade, it was found that there was comparatively little difference between the higher grades in the percentage of defective samples. In the Commercial grade, however, particularly in oats and barley, there was a conspicuously larger percentage of defective samples than in the higher grades (Table 7). The apparent uniformity in the percentage of defective samples in the higher grades appeared to be due to the fact that most of the defects were either not preventable or that no particular care was taken by seed growers to avoid them, except perhaps to control smut. Smut contamination was not extremely serious in the higher grades of seed (Table 8) but was very prevalent in samples of Commercial seed. Table 8 shows, too, that smut contamination in Commercial seed was decidedly less in wheat than in oats or barley. The difference may perhaps be accounted for by the fact that a part of the wheat crop grown in Canada during the period of the survey was resistant to bunt whereas the common varieties of oats and barley were not smut resistant. Another reason for the difference may be that it is a common practice among farmers to treat wheat seed for smut, but to sow oat and barley seed too frequently without treatment.

DISCUSSION

The survey of 8428 samples of cereal seed showed a surprisingly large range of species of fungi occurring in cereal seed. A large proportion of these species appeared to be innocuous inhabitants of the seed. The

TABLE 7.—PERCENTAGES OF UNSOUND SAMPLES IN EACH OF THE FIVE CANADIAN SEED GRADES OF WHEAT, OATS, AND BARLEY

Crop	Year	Grade				
		Foundation	Elite	Registered	Certified	Commercial
Wheat	1942	47.0	41.0	54.0	28.0	59.0
	1943	66.0	54.0	54.0	0.0	81.0
	1944	28.0	51.0	57.0	50.0	67.0
	1945	46.0	27.0	41.0	0.0	56.0
	Mean	60.5	41.7	51.5	40.0	64.3
Oats	1942	33.0	46.0	64.0	46.0	79.0
	1943	42.0	55.0	57.0	0.0	82.0
	1944	40.0	28.0	33.0	100.0	70.0
	1945	9.0	55.0	50.0	50.0	78.0
	Mean	36.0	45.7	53.0	50.0	77.1
Barley	1942	14.0	28.0	42.0	19.0	75.0
	1943	36.0	60.0	68.0	43.0	69.0
	1944	64.0	25.0	23.0	40.0	58.0
	1945	55.0	21.0	43.0	78.0	72.0
	Mean	43.5	34.2	41.2	38.0	69.6
Mean of crops		49.2	42.0	49.3	40.8	71.4

TABLE 8.—PERCENTAGES OF SMUTTED[1] SAMPLES IN EACH OF THE FIVE CANADIAN SEED GRADES OF WHEAT, OATS, AND BARLEY

Crop	Year	Grade				
		Foundation	Elite	Registered	Certified	Commercial
Wheat	1942	7.0	2.0	1.0	0.0	0.0
	1943	0.0	5.0	0.0	0.0	4.0
	1944	0.0	0.0	5.0	0.0	6.0
	1945	0.0	2.0	5.0	0.0	9.0
	Mean	1.5	2.2	2.8	0.0	5.9
Oats	1942	17.0	0.0	12.0	23.0	58.0
	1943	8.0	0.0	10.0	0.0	35.0
	1944	10.0	0.0	3.0	0.0	44.0
	1945	0.0	3.0	3.0	0.0	33.0
	Mean	7.7	0.8	8.0	15.0	44.8
Barley	1942	0.0	0.0	10.0	0.0	61.0
	1943	0.0	6.0	28.0	29.0	35.0
	1944	9.0	14.0	9.0	20.0	36.0
	1945	0.0	3.0	11.0	22.0	48.0
	Mean	2.6	5.4	12.2	14.3	48.0
Means of crops		3.5	2.3	6.9	11.8	35.2

[1] Load of smut spores on seed greater than 1 : 1,000,000 by weight in wheat, and 1 : 1,500,000 in oats and barley.

occurrence of coprophilous species and the preponderance of saprophytes suggest that invasion of the seed by a fungus may occur independently of parasitism, the frequency of invasion by a particular fungus being possibly determined by the amount of inoculum in the seed environment. The ubiquity and preponderance of infection by *Alternaria* (saprophytic species) lends support to this hypothesis. The comparative abundance of parasitic species of fungi in seed from Eastern Canada, without any reduction in saprophytes, does not seem to detract from the validity of this argument, for, as a group, these parasitic fungi are favoured by the moist weather often occurring in Eastern Canada.

It might be well to draw attention to the fact that the fungus flora observed in cereal seed bore a marked similarity to the fungus flora of the soil or of the air. In some respects this fact would indicate that most of seeds became infected by inoculum of soil origin, which, in some instances, was perhaps increased in amount through growth on living, susceptible plants.

SUMMARY

Over a 7-year period, 8428 samples of cereal seed were tested for various defects. All of them were passed through a test in non-sterile soil and a centrifuge test to determine the amount of infection by seedling-blight fungi, the percentage of seeds weakened by moulding, frost, or mechanical injury, and the degree of contamination with smut spores. Of these samples, 6204 were passed through a plating test to determine the amount and kinds of micro-organisms within the seed.

A total of 43 different genera (102 species) were identified among the fungi isolated from seed. Also, much of the seed appeared to carry unidentified yeasts and bacteria. Among the fungi, *Alternaria* was the most common genus, but *Helminthosporium* was the most common of the pathogens. Seed from Eastern Canada was, on the whole, more frequently infected by pathogenic fungi than was seed from Western Canada. Mechanical and frost injury, however, were more common in Western Canada than in Eastern Canada.

The proportion of defective samples was about the same in all the higher (Foundation, Elite, Registered, Certified) grades of seed. In the Commercial grade, the proportion of defective samples was larger than in any of the higher grades, a result due chiefly to a higher degree of smut contamination in the Commercial grade.

REFERENCES

1. Cherewick, W. J. An improved method of determining the smut spore load of cereal seed. Can. J. Res., *C*, 22 : 120-126. 1944.
2. Gordon, W. L. Species of *Fusarium* isolated from samples of cereal seed in Canada Phytopathology (Abstr.) 36 : 399. 1946.
3. Machacek, J. E., and H. A. H. Wallace. Non-sterile soil as a medium for tests of seed germination and seed-borne diseases in cereals. Can. J. Res., *C*, 20 : 539-557. 1942.
4. Mead, H. W., W. C. Broadfoot, and J. E. Machacek. A study of some seed-borne diseases of cereals in Canada. I. Comparison of seed testing techniques. Sci. Agr. 30 : 350-360. 1950.

THE EFFECT OF NITROGEN, PHOSPHORUS, POTASSIUM AND CHLORINE ON THE CAROTENE CONTENT OF THE CARROT[1]

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[Received for publication January 11, 1951]

INTRODUCTION

The carrot root (*Daucus carota*, L.) is a very fertile and relatively inexpensive source of carotene for experimental and nutritional purposes and has been the source of material for much research on carotenoids.

There appears to be general agreement that the carotene content of plants is directly associated with the supply of nitrogen available in the soil (1, 3, 4, 5, 7, 8, 10, 11, 12). Wynd and Noggle (10) go so far as to state that the amount of nitrogen is the most important chemical property of the soil in controlling the concentration of carotene in the leaves of oats. Pollard (8), however, found that the differences in the carotene values for carrots receiving different treatments were not very great but the values given by those receiving high nitrogen additions were uniformly greater than those receiving little or no nitrogen.

Brown *et al.* (3) found that potassium and phosphorus did not affect the carotene content of Lucullus Swiss chard, and Wynd and Noggle (10) also found that the amount of replaceable potassium and weakly acid soluble phosphorus appeared to have no relationship to the accumulation of carotene in the leaves of oats.

Pollard (8) found that the addition of chlorine in two cases gave intermediate values for carotene although the nitrogen supply was high. He was of the opinion that the production of carotene depends upon an adequate supply of nitrogen and may be adversely affected by the presence of chlorine.

Because of the especial importance of carrots and their carotene content in the dietary the following experiment was carried out to ascertain the effects of nitrogen, phosphorus, potassium and chlorine applied at varying levels at the usually recommended rate of fertilizer applications for growing carrots in coastal British Columbia.

MATERIALS AND METHODS

Field Work and General Procedure

Chantenay carrots were seeded on Monroe silt loam on June 23, 1949 in rows 14 inches apart. Each plot consisted of two test rows 12 feet long separated from the adjacent plot by a guard row. One foot at each end of the rows was discarded at harvest. The experiment was laid out in randomized block design and consisted of twelve treatments replicated five times. The blocks were laid out and soil samples taken from each block before fertilizing. Soil samples were analysed by the Spurway method (9). Fertilizer was applied at the rate of 1000 pounds per acre in drilled bands about 2 inches below seed level and 1-1½ inches on either side of the seed row.

[1] Part of a research project submitted to the Department of Horticulture of the University of British Columbia by the first named author in partial fulfilment for the degree of Master of Science in Agriculture.

[2] Horticulturist, Dominion Experimental Farm, Agassiz, B.C., and Professor, Department of Horticulture, University of British Columbia, respectively.

The fertilizer mixtures used were as follows:

Treatment No.	Mix	Treatment No.	Mix
1	0–10–10	7	4–20–10
2	4–10–10	8	4–10– 0
3	8–10–10	9	4–10–20
4	12–10–10	10	0– 0– 0
5	16–10–10	11	12–10–10*
6	4– 0–10	12	12–10–20*

* The potassium fertilizer used in treatments 11 and 12 was potassium chloride (muriate of potash) while in all others potassium sulphate was used. The nitrogen source for all treatments was ammonium sulphate while superphosphate was used to supply the phosphorus.

Normal cultivation, weeding and thinning was carried out during the growing period, as well as one application of benzene hexachloride applied to control the carrot rust fly.

The crop was harvested on October 29, 128 days after sowing, and placed in common storage at the University.

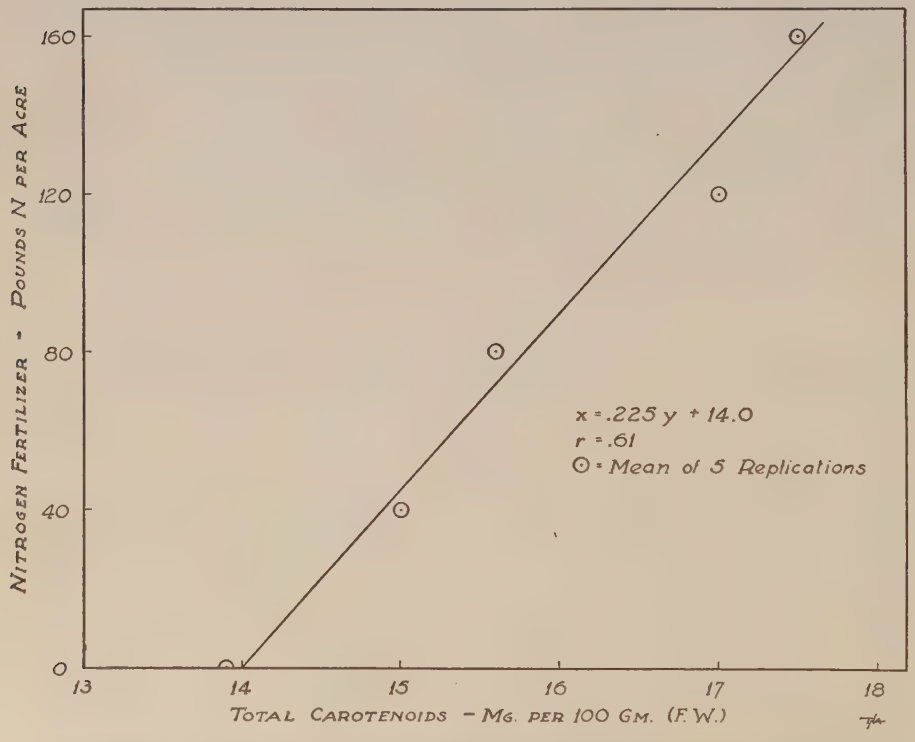

FIGURE 1. The effect of nitrogen on the carotene content of carrots (1949).

Laboratory Procedure

The carotene determinations were made by the sector method described by Booth (2) and outlined briefly as follows. Sectors were extracted with 3 : 2 petroleum-acetone mixture, and the total yellow pigment determined directly on this solution with a Klett-Summerson photo-electric colorimeter, using as a standard dichromate solution (6) equalling 3.5 mg. of carotene per litre standardized against pure carotene obtained from Research Laboratories, S.M.A. Corporation, Chagrin Falls, Ohio. The values so obtained are total carotenoids and expressed as mg./100 gm. fresh weight. Colorimetric equivalence is assumed between carotene and total carotenoids. Because total carotene rarely varies much from 90 per cent of the total carotenoids the latter offers a satisfactory criterion of vitamin A value for comparative purposes (2).

RESULTS

The analysis of the soil samples taken before the fertilizer was applied showed that the blocks were relatively uniform and that the soil was deficient in nitrogen and phosphorus but contained adequate potassium.

The results of the carotene determinations are presented in Figure 1 and Table 1. They indicate that nitrogen increased the carotene content of carrots. Figure 1 shows a steady increase in carotene with each additional increment of nitrogen. The correlation between the amount of nitrogen applied as a fertilizer and weight of carotene produced per unit gives $r = 0.61$ ($P = 0.01$). This relationship is expressed by the straight

TABLE 1.—THE EFFECT OF NITROGEN, PHOSPHORUS, POTASSIUM AND CHLORINE UPON THE CAROTENE CONTENT OF CARROTS

Treatment No.	Treatments N	P	K		Total carotenoids* (means of 5 replicates)
	(Levels)				(mg./100 gm. F.W.)
1	0	1	1		13.9
2	1	1	1		15.0
3	2	1	1		15.6
4	3	1	1		17.0
5	4	1	1		17.5
6	1	0	1		15.0
7	1	2	1		15.8
8	1	1	0		15.3
9	1	1	2		15.0
10	0	0	0		14.5
11	3	1	1	(Cl)	14.2
12	3	1	2	(Cl)	15.4

* L.S.D. ($P = 0.05$) = 1.2 mg./100 gm.

line formula $x = 0.225y + 14.0$ which is shown as the theoretical line in Figure 1. The points plotted on Figure 1 are the means of the five replications for each level of nitrogen. The r value was calculated from the 25 individual determinations and hence includes variability due to soil as well as chemical analysis.

Further study of these data show that when a comparison is made between treatments 2, 6 and 7, and 2, 8 and 9, respectively neither potassium nor phosphorus had any significant effect on the carotene content of the carrots.

In view of the fact that the soil was initially low in phosphorus it would appear that the results obtained with this element were fairly conclusive. However, since the initial potassium content of the soil before treatments was adequate the effect of the potassium treatments cannot be regarded entirely as conclusive.

In treatments 11 and 12 where potassium chloride was substituted for potassium sulphate even though the nitrogen level was high the carotene content of the carrots from these plots was less than that in those carrots from plots where an equivalent amount of potassium sulphate had been added (treatment 4) and in fact, was not significantly different from that in those carrots grown in plots where no fertilizer was added (treatment 10).

DISCUSSION

The results obtained in this experiment with carrots are in general agreement with those obtained by workers, previously mentioned, on other crops, namely nitrogen did increase the carotene content of the crop at rates of application used upon an initially nitrogen-deficient soil. The results were more striking than those reported by Pollard (8) who only obtained real differences between carrots from plots which received high nitrogen treatments and those which received little or no nitrogen.

The fact that no increase in carotene content was obtained by increasing the phosphorus fertility level (treatments 2, 6 and 7) or the potassium fertility level (treatments 2, 8 and 9) is in agreement with the results obtained by Brown *et al.* (3) and Wynd and Noggle (10) who also were unable to attribute any especial effect on carotene production to these elements.

It would appear that the substitution of the chloride for the sulphate in the potassium treatments has a detrimental effect on carotene synthesis. This toxic effect of the chloride ion would tend to confirm the conclusion of Pollard (8) that the production of carotene may be adversely affected by its presence.

SUMMARY AND CONCLUSION

When the commercial rates of fertilizer mixtures of varying levels of nitrogen, phosphorus and potassium were added to a Monroe silt loam low in nitrogen and phosphorus but containing adequate potassium the following conclusions were derived in respect to the carotene content of carrots grown on this soil:

Addition of increasing increments of nitrogen progressively increased the carotene content of carrots.

No significant effect on the carotene content was noted by additions of phosphorus.

While no effect on the carotene content was obtained by additions of potassium, the initial potassium level of the soil before treatments was adequate and therefore could be responsible for the lack of response to further additions of this element.

The presence of chlorine in the fertilizer mixture was detrimental to the formation of carotene.

REFERENCES

1. Bernstein, L., K. C. Hamner, and R. Q. Parks. The influence of mineral nutrition, soil fertility, and climate on carotene and ascorbic acid content of turnip greens. Plant Physiol. 20 : 540-571. 1945.
2. Booth, V. H. Simplified procedure for estimation of total carotenoids in carrots. J. Soc. Chem. Ind. 64 : 194-196. 1945.
3. Brown, H. D., M. B. Patton, A. Blythe, and M. R. Shetlar. Influence of mineral levels upon carotene and ascorbic acid contents of Swiss chard grown in the greenhouse. Food Research 12 : 4-9. 1947.
4. Ellis, G. H., and K. C. Hamner. The carotene content of tomatoes as influenced by various factors. J. Nutrition 26 : 539-553. 1943.
5. Ijdo, J. B. H. The influence of fertilizers on carotene and vitamin C content of plants. Biochem. J. 30 : 2307-2312. 1936.
6. Loomis, W. E., and C. A. Shull. Methods in plant physiology, pp. 132-133. McGraw-Hill Book Company Inc., New York and London. 1937.
7. McCoy, T., S. M. Free, Jr., R. G. Langston, and J. Q. Snyder. Effect of major elements on the niacin, carotene, and inorganic content of young oats. Soil Sci. 68 : 375-380. 1949.
8. Pollard, A. Note on the effect of manurial treatments on the carotene content of carrot roots. The Annual Report of the Agricultural and Horticultural Research Station, Long Ashton, Bristol, p. 32. 1941.
9. Spurway, C. H. Soil testing. Michigan State Coll. Agr. Exp. Sta. Tech. Bull. 132 (3rd revision). 1944.
10. Wynd, F. L. and G. R. Noggle. Influence of chemical characteristics of soil on production of carotene in leaves of oats. Food Research 10 : 525-536. 1945.
11. Wynd, F. L., and G. R. Noggle. Influence of chemical characteristics of soil on production of carotene in leaves of rye. Food Research 11 : 148-158. 1946.
12. Wynd, F. L., and G. R. Noggle. Relationship between phosphorus fractions in soil and carotene in leaves of cereals. Food Research 11 : 358-364. 1946.

POLYEMBRYONY IN ALFALFA[1]

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[Received for publication November 22, 1950]

Alfalfa *Medicago sativa* L. has a normal chromosome number of 2n = 32 and good evidence for autotetraploid inheritance has been presented by Ledingham (18) and Tysdal *et al.* (32). In autotetraploids a single factor difference with dominance gives a ratio between 35 : 1 and 19 : 1 compared with a 3 : 1 ratio in diploids (19). Haldane (11) has shown that it requires 3.80 generations of selfing to reach 50 per cent homozygosity in an autotetraploid compared to one generation in a diploid. Consequently, if the chromosome complement of alfalfa could be reduced to the diploid level it would greatly simplify the attainment of homozygous, or relatively homozygous, strains. Presumably diploids would be fertile, providing that the autotetraploid hypothesis is correct. After having purified the material for desirable plant characters, if necessary, it could be doubled back into the tetraploid condition with colchicine. It has been shown, in other species, that one member of a pair of twin seedlings frequently has the haploid chromosome number (24). The object of this study was to investigate twin seedlings of alfalfa as a source of diploid (2n = 16) plants.

For the sake of uniformity a basic genom number of 8 chromosomes has been assumed in naming the various polyploids of alfalfa.

LITERATURE REVIEW

Cooper (6), Tome (30), Nilsson and Anderson (23) and Julen (13) have reported polyploids in *Medicago sativa* with a 2n = 64 chromosome number. Cooper obtained a single 2n = 64 plant by heat treatment at 42° C. 47 to 48 hours after pollination. This polyploid was similar to common alfalfa in growth habit. It had stouter stems, larger leaves, flowers, stomata, epidermal cells, and pollen grains than common alfalfa. This induced octaploid was almost completely self-sterile; only 2 seeds were obtained and the resulting plants had a chromosome number of 2n = 64. Tome (30) found a natural octoploid in the field and said the frequency of occurrence was about 1 in 3000 plants and that such plants could be picked out by their agronomic characters. Nilsson and Anderson (23) and Julen (13) developed octoploids (2n = 64) chromosomes by the use of colchicine. By crossing the 2n = 64 plants to 2n = 32 plants they obtained two hexaploids (2n = 48). Julen reported further in 1944 that the vigour of the octoploids dropped considerably after the first year and they were less vigourous than the hexaploids or ordinary tetraploid plants. The hexaploids outyielded their parents in forage, but both being members of the same pair of twins it was impossible to get comparable data on seed yield. It was difficult to determine whether the increased vigour was due to the 2n = 48 chromosome number or to heterosis. Meiosis in the tetraploid and hexaploid was very uniform, while lagging chromosomes and other anaphase disturbances were quite common in the octoploid.

[1] Contribution from the Dominion Forage Crops Laboratory, Saskatoon, Sask., being a condensation of a thesis submitted to the Graduate School of the University of Saskatchewan in partial fulfilment of the degree of Master of Science.

[2] Agricultural Research Officer.

Bolton and Greenshields (2) reported a diploid (2n = 16) chromosome strain of *Medicago sativa*. However, this diploid has not been doubled yet yet to a 2n = 32 chromosome plant to test crossing with a 32-chromosome *Medicago sativa*. Schelhorn (26) stated that in *Medicago falcata* the transition of the diploid type to the tetraploid type took place naturally in some areas of central Europe and Asia.

Polyembryony in alfalfa has been reported by Southworth (29), Skovsted (27) and by Martin and Watt (20). Of these authors only Skovsted reported on the cytology of his material. He studied seven pairs of twins of *Medicago sativa* and reported one pair as aneuploids with chromosome numbers of 2n = 31 and 2n = 33, respectively. The remainder had the normal chromosome number of 2n = 32.

Polyembryony in many species has been associated with varying chromosome numbers. Harland (10) and Cooke (4) were interested in haploid plants because by doubling they were able to produce truly homozygous lines. Harland found that out of 16 sets of twins in *Sea Island Cotton* one member of one pair was haploid. By using decapitation he doubled the haploids to obtain homozygous lines in a crop in which selfing is difficult. Cooke (4) reported a haploid *Mariglobe* tomato plant. By self-pollination be obtained a homozygous pure line, due to the fertilization of an unreduced egg by an unreduced pollen grain. Bartlett and Haldane (1) have shown mathematically how much more efficient in time and expense such a method of producing a pure line can be, wherever it is biologically feasible.

Cooper (7) and Cameron (3) reported multiple seedlings in *Nicotiana*. Cameron stated that in a year when the germination was below normal there was a corresponding deficiency in the frequency of multiple seedlings. The twin seedlings resulting from cleavage were conjoined, while twins of other origins were not. The fact that one member of a pair was often weak indicated competition between embryos for food material. Cameron was certain that in one pair of twins one member of one pair had resulted from sporphytic budding. Cooper states that the haploid member of a pair most likely developed parthenogenically and its position indicated that it developed from a synergid. In approximately 1 per cent of ovules examined Cooper states that a synergid had been stimulated to divide but usually disintegrated at an early stage of development.

Kasparyan (15), Yamamota (35), Yamasaki (36), Yamazaki (37), Namikawa and Kawakami (22) and Kreshnaswamy (16) all worked on polyembryony in the Genus *Triticum*. Haploids (2n = 21), triploids (2n = 63) and tetraploids (4n = 84) were reported.

Yamamota (35) found triplo-diplo twins were more common in his material than haplo-diplo twins and suggested there might be a variety difference in this regard. Triploids were in his opinion the result of apomixis. Kasparyan obtained twins from interspecific crosses while Kreshnaswamy and Yamazaki obtained their haploid plants from *Triticum vulgare*. Kasparyan found one pair of twins with 2n = 35 and 2n = 49 chromosome numbers, respectively. The 2n = 35 plant was the normal result of a 2n = 28 ♂ plant × a 2n = 42 ♀ plant, while he explained the other member of the pair by assuming that an unreduced pollen grain had fertilized a normal female egg.

Johnson (12) in *Eugenia Hookeri*, Randall and Rick (24) in *Asparagus officinalis* L. and Kappert (14) in flax indicated that the genotype was responsible for the occurrence of polyembryony. Kappert increased the occurrence of twins by selfing for four generations and suggested that the phenomenon might be governed by recessive genes.

Lamm (17) working on potatoes obtained a haploid twin member from a tetraploid interspecific cross. The (2n = 24) haploid was completely fertile and gave stable offspring. Elliot and Wilsie (8) reported a fertile polyploid in *Bromus inermis* in a study of twin seedlings.

Watt and Martin (33) found alfalfa and sweet clover seeds with double embryo sacs. These embryo sacs were arranged in a manner, that the seed containing them was not appreciably larger than a seed containing a single embryo sac.

MATERIAL AND METHODS

The material in this study was largely from the varieties Ladak and Grimm. Both these varieties have variegated flowers and are often classified as *Medicago media* Pers. For comparison *Hardistan*, a selection from Turkistan alfalfa (*M. sativa*) and two strains of *M. falcata*, S-914 (2n = 32) and S-33-$\bar{1}$ (2n = 16), were examined.

The most efficient method of obtaining twins consisted of germinating seeds between moist paper towels. On about the third day of germination the sprouted seeds were examined for the projection of two radicles from the one seed. By a count of the total germinated seeds, it was possible to calculate the frequency of twinning. The twins were then placed in a Petri dish on a moist paper towel until they had thrown off the seed coat. The seedlings were then planted in small pots. A culture described by Tukey (31) was used to carry some of the weak seedlings for the first 4 or 5 days.

In 1947 the first five pairs of twin seedlings and two plants which were members of twin pairs were obtained. The group of twelve plants were diallel crossed in the greenhouse during the winter of 1947-48. Seed from these crosses was planted in greenhouse flats in February, 1949. When these seeds emerged 4 pairs of twins were picked out of the flats, one pair being conjoined.

This intercrossed material was planted in the field in May, 1949. The plants were spaced 15 inches apart in the rows with rows 3 feet apart. Reciprocal crosses were situated adjacent to each other. In the two rows adjacent, the same outcross reciprocal of the other twin member of the pair were planted. In September, 1949, single plant yields were taken. Each plant was harvested separately, and the dry and green weights recorded.

During the winter of 1948-49, 50 twin pairs were identified by germinating the seed. In addition 4 pairs of twins were picked out of the flats. One set of triplets were found in which two seedlings were equal to each other in size, and larger than the third member. The smallest member died after 2 weeks and before it could be examined cytologically.

Observations were made of twin pairs based on flower colour, leaf characteristics and chromosome number.

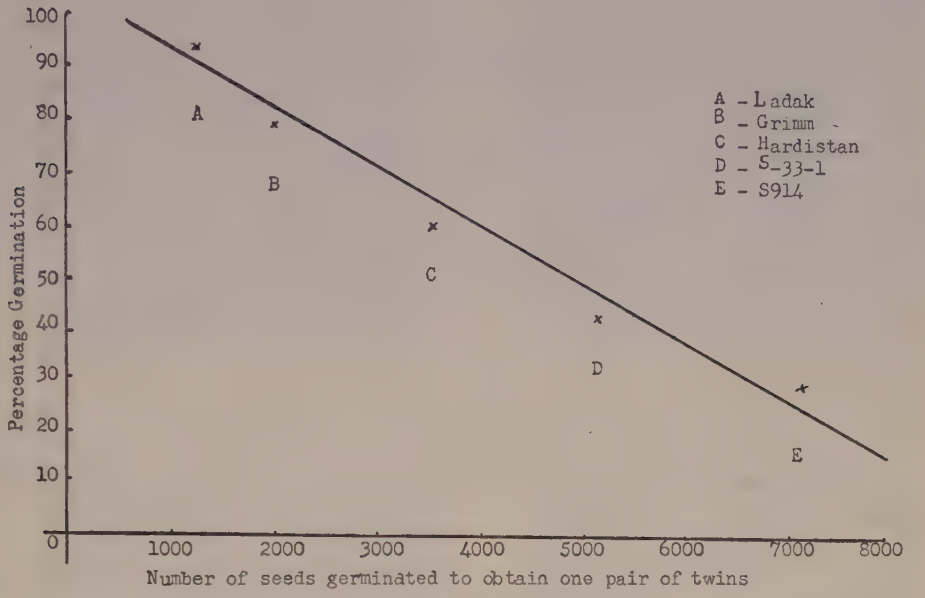

FIGURE 1. Relationship between percentage germination and frequency of twinning in alfalfa.

In the cytological investigation the method employed was a modification of Smith's (28) acetocarmine smear technique for root tips. Root tips were collected from either plants growing in pots or from cuttings rooted in running water as described by White (34). The latter source proved highly satisfactory since there were no soil particles present to adhere to the root tips.

When the root tips were about one-half inch long the cuttings were placed in a saturated solution of paradichlorobenzene for half an hour at room temperature, after which they were removed and the root tips were clipped off into a 3 : 1 solution of 95 per cent ethyl alcohol and glacial-acetic acid. The root tips were left in the solution for at least 24 hours before smear slides were made. Root tips were hydrolyzed in a solution of 1 : 1 concentrated hydrochloric acid and 95 per cent ethyl alcohol for $3\frac{1}{2}$ to 4 minutes and then returned to cold 3 : 1 alcohol-acetic acid.

After at least 3 or 4 minutes in the 3 : 1 alcohol-acetic solution, smear-slides were made by macerating a root-tip on a slide in a drop of aceto-carmine. The slide was heated for 30 seconds to 1 minute over a steam bath and the cover slip was pressed firmly to flatten and spread the material. Photographs of chromosome plates were taken under the microscope with an Argus 32 mm. camera. Photographic exposures were facilitated by the use of a ride-the-microscope camera mount.

Some time was spent in developing a method of making permanent slides. Removal of the cover slip by floating off in 3 : 1 alcohol-acetic acid and replacement of the cover slip on a drop of diaphane gave satisfactory slides although often much of the material was lost. A more satisfactory method was to use a 3 : 1 solution of absolute ethyl alcohol and Venice turpentine. The cover slip was not removed by this method.

Immediately after spreading much of the acetocarmine was displaced. The cover-slip was then eased up slightly with a razor blade, causing the acetocarmine to run to the far side of the cover-slip. Two or three drops of Venice turpentine are then placed at the raised edge of the cover-slip where it quickly runs under permanently displaying the acetocarmine, which is then blotted off the slide. After a period of six months the figures on these slides have not deteriorated.

EXPERIMENTAL RESULTS

Frequency of Twinning

Frequency of twinning studies were carried out in the four varieties and strains which have been mentioned above. The data obtained are summarized in Figure 1.

Figure 1 indicates that the higher the germination percentage, the higher is the occurrence of twin seedlings; however, this result may have been coincidental with varieties producing twins in this sequence regardless of germination.

Types of Twinning

There were three types of twins noted in this study:

(*a*) Equal twins: Those which had two radicles at germination of equal length and which were in no way joined together when the seed coat was removed (*see Figure 2*).

(*b*) Unequal twins: Those pairs which had one radicle much larger than the other and were not joined in any way when the seed coat had been removed (*see Figure 3*)

(*c*) Conjoined twins: Those which had the radicles more or less fused from the root tip to the base of the four cotyledons (*see Figure 4*).

Comparison of Twins

Fifty pairs of twins were compared morphologically. Two characters were used as a basis of comparison. The flower colour of members of a pair of twins was used as one character, while leaf characteristics were used as the other standard of comparison. The best leaf character for comparison was the saw-toothed notches at the ends of the leaflets. By measurement the notches varied from 0-3 mm. The results are summarized in Table 1.

TABLE 1.—COMPARISON OF FLOWER COLOUR AND LEAF CHARACTERISTICS OF TWIN PAIRS

Flower colour		Leaf characteristics	
Alike	Unlike	Alike	Unlike
15	1	48	2

Two pairs of twins showed detectable differences in leaf characteristics, while only one pair deviated in flower colour. The flower colour data are incomplete because many of the plants have not flowered.

FIGURE 2. An equal pair of twins as they emerged from the seed.

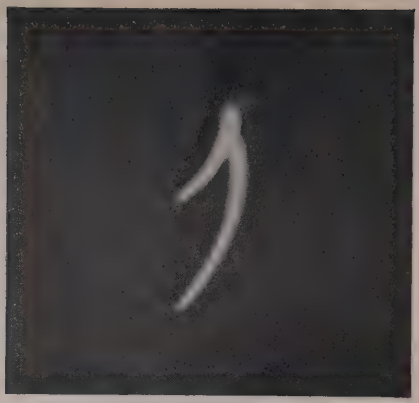

FIGURE 3. An unequal pair of twins as they emerged from the seed.

FIGURE 4 (*a*). The radicles of a pair of conjoined twins protruding from a seed.

FIGURE 4 (*b*). The same pair of conjoined twins as in Fig. 4 (*a*) with the seed coat removed.

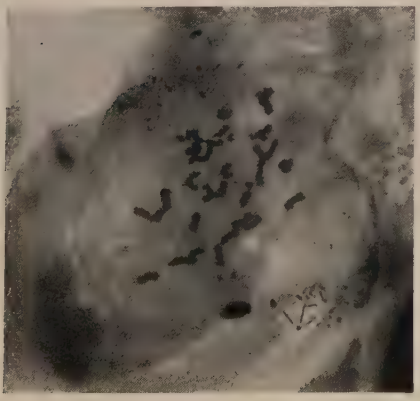

FIGURE 5. A 32-chromosome cell showing 4 chromosomes with satellites. Mag. approx. 2000X.

FIGURE 6. A 64-chromosome cell from an octoploid area of a root. Mag. approx. 2000X.

Comparison of the combining ability of twins was carried out by two methods of analysis. In the first place, green yields of the progeny of twin pairs were analysed to determine whether members of a pair were significantly different in specific combining ability.

These data showed that one pair of twins out of the five pairs tested were significantly different in combining ability. The t-value—4.8270 between S-47-$\overline{34}$ and S-47-$\overline{35}$ was significant at the 1 per cent level. However, the number of pairs tested is not sufficient to establish the proportion of twin pairs that would differ from one another in a large population. The reciprocal progeny of twin pairs did not differ significantly in yield; therefore averages per plant were based on the total progeny of a cross.

Secondly, where twin pairs showed no difference, they were considered as one plant. The general combining ability of S-47-$\overline{34}$ and S-47-$\overline{35}$ were each compared with the other four pairs of twins. The results of the comparison are given in Table 2.

TABLE 2.—MEMBERS OF TWIN PAIRS WHICH ARE NOT SIGNIFICANTLY DIFFERENT TAKEN AS ONE PLANT AND THE AVERAGE GREEN WEIGHT PER PLANT COMPARED TO S-47-$\overline{34}$ AND S-47-$\overline{35}$ BY MEANS OF A T-TEST

	Listed in the table are the t-values	
	S-47-34	S-47-35
S-47-$\overline{26}$ S-47-$\overline{27}$	0.2979	2.2856*
S-47-$\overline{28}$ S-47-$\overline{29}$	0.5783	2.3082*
S-47-$\overline{30}$ S-47-$\overline{31}$	1.0641	1.4544
S-47-$\overline{32}$ S-47-$\overline{33}$	2.2794	1.0537
S-47-$\overline{34}$	—	4.8270**
S-47-$\overline{35}$	—	—

e.g. 0.2979—t-value for a comparison between average yield of S-47-26 and -27 with S-47-34.
* Significance at the 5 per cent level.
** Significance at the 1 per cent level.

These data show that S-47-$\overline{34}$ was not significantly different in yield from any of the tested population, while S-47-$\overline{35}$ was significantly different from one-half of the group tested.

Chromosome Numbers

The cytology of all the twins reported here was studied with particular reference to chromosome numbers. All pairs of twins were estimated to have 32 chromosomes as the normal complement for each member. Certain irregularities were noted. In some, root tip material from the 16-chromosome strain of *M. sativa* reported by Bolton and Greenshields (2) was examined for comparison with the material under study. In this material two cells were noted with the reduced number of 8 chromosomes. Another

irregularity in the root-tips of the twins was the presence of octoploid areas with a chromosome number of 64. These areas appeared to consist of a considerable number of cells. The cells appeared larger than normal but this characteristic could not be determined definitely due to distortion from spreading process. A typical cell with 64 chromosomes is shown in Figure 6 together with a normal 32-chromosome cell for comparison in Figure 5.

DISCUSSION

Harland (10) in cotton and Cameron (13) in Nicotiana obtained fertile haploid plants from among twin seedlings of these species. In both cases the haploids were fertile diploids. This confirmed theoretical expectations, since *Sea Island Cotton* and *N. tabacum* are both autotetraploids. Similarly Elliot and Wilsie (8) reported a fertile polyhaploid in *Bromus inermus* in a study of twin seedlings. Since it seems likely that *Medicago sativa* ($2n = 32$) is of autotetraploid origin it was thought that twin seedlings would provide a source of fertile diploids of this species. However, no diploid individuals were identified in this study of 55 pairs of twins. Apparently the origin of twins in *M. sativa* is of a type which does not ordinarily produce pairs with other than the tetraploid chromosome numbers.

Martin and Watt (20) found twin embryo sacs in *Melilotus alba*. Cooper (5) often found two well developed gametophytes in one ovule in alfalfa. If twin seedlings in alfalfa are mainly due to the production of double embryo sacs the diploid or other members in the euploid series would not likely occur. From the data obtained it is evident that twins studied are either identical or very similar to one another. The data on leaf character indicate that at least 4 per cent of twin pairs differ from one another and must be either the result of double embryo production or one member has arisen through sporophytic budding. If the result of double embryos they would be sibs, but if one member were the result of sporophytic budding they would bear the relationship of mother to daughter. Cleavage of the fertilized egg at a very early stage or double sporophytic budding of the nucellus or integument would satisfactorily explain identical twins.

An experiment could be carried out to determine whether or not members of twin pairs are the result of fertilization. The factors for white flower colour in alfalfa are recessive to the factors for coloured flowers. A homozygous coloured-flowered plant could be placed in isolation with a homozygous white-flowered self sterile-plant. The seed would be harvested from the white-flowered plant, germinated, and examined for twin seedlings. Among the twin plants those showing colour would be the result of fertilization, while plants that were white would be the result of sporphytic budding, the development of an unreduced egg cell or the stimulation of a synergid or antipodal cell. This latter group would have the diploid chromosome number. Since polyembryonic plants which are the result of fertilization are not likely to be other than tetraploid, a large percentage of the population could be eliminated on a flower colour basis. Evidence indicates that most of the twin plants of this study are the result of double embryo sacs or cleavage at an early stage of embryo development.

If so, and if the white flower method had been used, they could have been eliminated at once without cytological examination. If any white-flowered twin members had occurred the investigator would have known that he was working in the section of the population where a 2n = 16 diploid might be found.

Conjoined twins are probably the product of a single embryo sac and also offer a means of eliminating twins originating from multiple embryo sacs. In some instances in alfalfa it is difficult to determine whether there is complete fusion, or one individual with three or four cotyledons. The following range of fusion was encountered:

1. 4-cotyledons fused at the base of the cotyledons with the radicles free, each pair of cotyledons having a growing point.
2. 4-cotyledons fused from the tips of the radicles to the base of the cotyledons, having two growing points.
3. 4-cotyledons on what appears to be a single radicle having one growing point.
4. 3-cotyledons on a single radicle, having two growing points.
5. 3-cotyledons on a single radicle, having a single growing point.
6. 2-cotyledons on a single radicle having two growing points.

If some of these types are fused twins, one plant could be diploid and the other tetraploid. Only two pairs of conjoined twins were examined in study. Both pairs were tetraploid; however, they were both type 1 of the above classification and they represent too small a sample to test the above hypothesis. It is therefore possible that some diploids may have been overlooked in the present study.

Other authors have experienced difficulty getting diverse euploid plants as derivatives of normal (2n = 32) *M. sativa*. The triploid (2n = 24) was obtained by Ledingham (18). The octaploid (2n = 64) has been induced by Copper (6) and Nilsson and Anderson (23) and isolated by Tome (30), but only in Cooper's experiment did the 2n = 64 seed develop on the normal (2n = 32) plant. Excluding the tetraploid, it is conceivable that, due to genetic unbalance, the triploid is the most easily obtained plant of the whole euploid series. Considering a 1 : 1 ratio as being optimum for zygotic development the following sequence illustrates how different combinations may result in different degrees of genetic balance:

Parent	Zygote	Ratio
Tetraploid	Diploid	1 : 0.5
Tetraploid	Triploid	1 : 0.75
Tetraploid	Hexaploid	1 : 1.5
Tetraploid	Octoploid	1 : 2

The triploid deviates less from the tetraploid 32-chromosome alfalfa than any other euploid possibility. This fact is born out morphologically as they resemble one another very closely. Triploid, hexaploid and octoploid combinations have been found developing on a 2n = 32 parent. Muntzing's (21) data showed that triploids occurred more readily than haploids or tetraploids. He found in 11 genera that 2201 pairs of twins gave 77 triploids, 11 haploids and 2 tetraploids.

In Figure 5 four satellites are shown on chromosomes that are very similar morphologically. In the diploid *M. sativa* reported by Bolton and Greenshields two satellites are present. It is suggested that the above situation with regard to satellite chromosomes is further evidence of the autotetraploid origin of *M. sativa*. However, Cooper (7) has shown 2 satellites in *M. sativa* (2n = 32) and Fryer (9) has shown 2 satellites in many 2n = 16 species of *Medicago*. Thus the possibility of both an allotetraploid and diploid origin cannot be excluded. Cooper's result may not be contradictory, because it is difficult to get a figure showing all four satellites clearly, or different lines may vary in chromosome morphology.

Polyembryony in alfalfa may be inherited. Four pairs of twins were obtained in the progenies of crosses between plants of polyembryonic origin. This would make a frequency of twinning of 1 in 500 plants, while our best variety tested only gave twin pairs at 1 in 2000 plants. This differences should not be overlooked, although it may have been caused by differences in the age of the seed tested. Kappert (14) in *Linum usitatissimum* L. studied different lines. One line did not give twin seedlings, while the other line gave 0.4 per cent twinning. In the F_2 generation of a cross between the two lines the progeny segregated with respect to the occurrence of twins. Kappert concluded that polyembryony was a property of the mother plant and that environmental conditions may affect the expression of polyembryony in the progeny.

Sansome and Philip (25) mention the induction of parthenogenesis by the crossing of distinctly related species. The foreign pollen acts as a stimulus to cause parthenogenic development of the egg-cell. Alfalfa should lend itself well to such experiments, because there are many distantly related species in the genus *Medicago* that could be used as a pollen source.

SUMMARY

1. A cytological investigation of fifty-five pairs of twins of *M. sativa* L. showed each member of all pairs had 2n = 32 chromosomes. It was concluded that twinning in alfalfa was generally the result of cleavage of a normal zygote, or else normal fertilization occurring in double embryo sacs.

2. Out of 5 pairs of twins 1 pair was shown to differ in combining ability; out of 16 pairs 1 pair was shown to differ in flower colour; and out of 50 pairs 2 pairs were shown to differ in leaf morphology.

3. Frequency of twinning appeared to be directly proportional to the viability of the seed.

4. A procedure is outlined using self-sterile white-flowered plants whereby it can be determined whether members of a twin pair are the result of sexual fusion or apomictic development. It is suggested that this procedure would enable a worker to concentrate cytological work on the portion of the population where diploid individuals are likely to occur.

5. It is suggested that various types of fusion in alfalfa twin seedlings may offer a richer source of diploid material since plants originating from multiple embryo sacs would be eliminated.

6. Diploid and octoploid areas were observed in root tips of tetraploid plants. It is suggested that shoots may originate from these areas.

7. One triplet seedling was discovered.

8. Four chromosomes with satellites are presented as further evidence of the autotetraploid origin of common alfalfa.

9. A satisfactory cytological technique for making acetocarmine smear slides has been described. It was found that these slides could be made permanent with Venice turpentine without removal of the cover-slip.

ACKNOWLEDGMENTS

The writer wishes to acknowledge his sincere gratitude to J. L. Bolton of the Dominion Forage Crops Laboratory, Saskatoon, whose supervision, advice and encouragement were invaluable in both the approach to the problem and the interpretation of data. Sincere thanks are extended to W. J. White, Officer-in-Charge, Dominion Forage Crops Laboratory, Saskatoon, for helpful criticism and advice. R. P. Knowles gave very valuable and much appreciated assistance with cytological technique and photography. Thanks are due to F. Rose, G. Morrison and other members of the staff for their assistance in numerous ways.

REFERENCES

1. Bartlett, M. S., and J. B. S. Haldane. The theory of inbreeding in autotetraploids- J. Gen. 29 : 175-180. 1934.
2. Bolton, J. L., and J. E. R. Greenshields. A diploid form of *Medicago sativa* L. *In Press* (Science).
3. Cameron, D. R. Inheritance in *Nicotiana tabacum*. Amer. J. of Botany 36 : 526-529. 1949.
4. Cooke, R. C. A haploid Mariglobe tomato. J. of Hered. 27 : 433-435. 1936.
5. Cooper, D. C. Macrosporagenesis and embryology of *Medicago*. J. Agr. Res. 51 : 471-477. 1936.
6. Cooper, D. C. Artificial induction of polyploidy in alfalfa. Amer. J. Bot. 26 : 65-67. 1939.
7. Cooper, D. C. Haploid-diploid twin embryos in *Lillium* and *Nicotiana*. Amer. J. Bot. 30 : 408-413 1943.
8. Elliot, F. C., and P. C. Wilsie. A fertile polyploid in *Bromus inermis*. J. of Hered. 39 : 377-380. 1948.
9. Fryer, J. R. Cytological studies in *Medicago*, *Melilotus*, and *Trigonella*. Can. J. Res. 3 : 3-50. 1930.
10. Harland, S. C. Haploids in polyembryonic seeds of Sea Island Cotton. J. of Hered. 27 : 229-231. 1936.
11. Haldane, J. B. S. Theoretical genetics of autopolyploids. J. Gen. 22 : 359-372. 1930.
12. Johnson, A. M. Polyembryonic in *Eugenia Hookeri*. Amer. J. of Bot. 23 : 83-88. 1936.
13. Julen, G. Investigations on diploid, triploid, tetraploid lucerne. Hereditas 30 : 567-582. 1944.
14. Kappert, H. Erblicke polyembryonic bei *Linum usitatissimum* L. (In German, summary translated). Biol. Zentralblatt 53 : 276-307. 1933.
15. Kasparyan, A. S. Haploids and haplo-diploids among hybrid twin-seedlings in wheat. Compt. Rend. Acad. Sci. (Koklady), U.S.S.R. 20 : 53-56. 1938.
16. Kreshnaswamy, N. Cytological studies in a haploid plant of *Triticum vulgare*. Hereditas 25 : 77-86. 1949.
17. Lamm, R. A. Notes on a haploid potato hybrid. Hereditas 24 : 391-396. 1938.
18. Ledingham, G. F. Cytological and developmental studies of hybrids between *Medicago sativa* and a diploid form of *M. falcata*. Genetics 25 : 1-15. 1940.
19. Little, T. M. Gene segregation in autotetraploids. Bot. Rev. XI : 60-85. 1945.
20. Martin, J. N., and J. R. Watt. Irregular sporogenesis and polyembryony in some Leguminosae. Iowa State Coll. J. Sci. 8 : 303-307. 1934.
21. Muntzing, A. Polyploidy from twin seedlings. Cytologia, Jubilee Volume: 211-227. 1937

REFERENCES—Concluded

22. Namikawa, S., and J. Kawakami. On the occurrence of the haploid, triploid and tetraploid plants in twin seedlings of common wheat. Proceedings of Imperial Academy, Tokyo, 10 : 668-671. 1934.
23. Nilsson, and Sver Anderson. Utsa. Tid. (Quoted by Julen G., Investigations on diploid, triploid, and tetraploid lucerene.) Hereditas 30 : 567-582. 1944.
24. Randall, T. E., and C. M. Rick. A cytogenetic study of polyembryony in *Asparagus officinalis* L. Amer. J. Bot. 32 : 560-569.
25. Sansome, F. W., and J. Philip. Recent advances in plant genetics. 2nd edition. Blakiston's Son & Co., Philadelphia, Pa. 1939.
26. Schelhorn, M. V. Zur Cytogenetik von *Medicago falcata*. Zütcher 1964 : 17/18 : 92-93 (abstract only). Plant Breeding Abstracts 18 : 748.
27. Skovsted, A. Cytological studies in twin plants. Carlsberg Laboratoire, Comptes Rendus. Serie Physiologique 22 : 427-442. 1940.
28. Smith, L. The aceto-carmine smear technic. Stain Technology 22 : 17-31. 1947.
29. Southworth, W. Twinning in alfalfa. J. of Hered. 10 : 182-183. 1919.
30. Tome, G. A. Two cases of polyploidy in lucerene. Rev. F. Agron. B., 11 : 299-307. Herb. Abs. 18 : No. 795.
31. Tukey, H. B. Artificial culture methods for isolated embryos of deciduous fruit. Proc. Amer. Soc. Hort. Sci. 32 : 313-322. 1935.
32. Tysdal, H. M., T. A. Kiesselbach, and H. L. Westover. Alfalfa breeding. Univ. of Neb. Exp. Sta. Res. Bull. 124. 1942.
33. Watt, J. R., and J. N. Martin. Polyembryony in alfalfa and sweet clover. Proc. Iowa Acad. Sci. 37. 1931.
34 White, W. J. An improved method of rooting alfalfa cuttings. Sci. Agr. 26 : 5. 1946.
35. Yamamoto, Y. Bot. Mag. 50 : 573-583. 1936. (In German—translated).
36. Yamamoto, Y. Uber das Vorkommen von triploiden Pflanzen bei Mehrlingskeimlingen von *Triticum vulgare*. (In German—translated) Cytologia 7 : 431-436. 1936.
37. Yamasaki, Y. Cytologia 5 : 305-307. 1934.
38. Yamazaki, Y. Some notes on twin plants of common wheats. (English summary) Jap. J. Gen. 13 : 193. 1937.

BOOK REVIEWS

THE SMUT FUNGI, by George W. Fischer. The Ronald Press Company, New York. 387 pp. 1951. Price $6.00.

The task of gathering literature on research problems is arduous and time-consuming and will become more so with the passage of time. Most workers will agree with the author of *The Smut Fungi* that "The answer appears to lie in extensive and exhaustive bibliographic reviews". For most topics such compilations might suffice, but the research worker should not get into the habit of using them to the complete exclusion of a further search through the literature.

The work under review is a guide to more than 3,000 literature references on the biology and control of some 330 species of the smut fungi and the diseases they cause. It is a valuable and welcome contribution in this field. The book is divided into a subject-matter guide of 217 pages, a bibliography of 117 pages and an index. The subject-matter references under each species are grouped chronologically under control, and phases of the biology of the species as follows: culture on artificial media; cytology; heterothallism and sex; hybridization and genetics; life-history, parasitism and factors affecting; longevity of spores; miscellaneous records; physiologic specialization; spore germination and factors affecting; and varietal resistance and susceptibility. The author has followed the nomenclature and synonymy in George L. Zundel's monograph on *The Ustilaginales of the World*. This has been done to make the present guide "as useful as possible" even though Zundel's concept of many species are not in agreement with those of the author. This attitude has much to commend it. In the preface the hope is expressed that subject-matter specialists in allied fields will prepare similar reviews. With this there should be general agreement. In order to make such compilations as useful as possible and financially available to the greatest number of low-salaried workers, book-making costs should be kept to a minimum. The present work is suitably arranged, easy to use and reasonably priced. If, however, more efficient use of space in the subject-matter section had resulted in even a slight reduction in the cost, it would have been all to the good. As a selected, reliable literature guide all workers on the smut fungi will find this work very valuable and time-saving.

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University of Saskatchewan.

COPPER METABOLISM: A SYMPOSIUM ON ANIMAL, PLANT AND SOIL RELATIONSHIPS. Edited by William D. McElroy and Bentley Glass. The Johns Hopkins Press, Baltimore. VIII + 443 pp. 1950. $6.00.

The Commonwealth Agricultural Bureaux held a meeting in Australia in 1949 to deal with Soil, Plants and Animals in relation to soil and climate. One of the resolutions passed by the delegates reads as follows: "That studies on the interrelation of soils, plants and animals in the field of

mineral nutrition should be brought together in critical reviews, each of which should feature a single element with full discussion of known interactions with other elements".

This symposium, as sponsored by the McCallum-Pratt Institute of The Johns Hopkins University, meets all the thoughts as expressed by delegates supporting the above resolution. The speakers were selected from the active workers in the United States, Australia and New Zealand and truly represent specialists from the various phases of investigations. Each paper is followed by a record of the ensuing discussion. The book concludes with a summary of the complete deliberations and Dr. Glass has done an excellent task in highlighting and focusing the submitted evidence upon the role of copper in plants and animals. Research workers in the fields of soil fertility, plant and animal nutrition should both read and study this outstanding book. It is hoped that symposia will be convened to deal with other trace elements in a similar manner.

J. C. Woodward,
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Canada Department of Agriculture.

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5. The H bomb. Introduction by Albert Einstein. Contributors: Stewart Alsop, Atomic energy commission, Robert F. Bacher, H. W. Baldwin and others. New York, Didier, 1950. 175 p.
6. The intelligence of animals. G. C. Grindley. London, Methuen & co., ltd. 70 p. (Methuen's monographs on philosophy and psychology)
7. Technical journalism. Third edition, revised. F. W. Beckman, Harry R. O'Brien, and Blair Converse. Ames, Iowa state college press, 1946. 443 p.
8. Report preparation, including correspondence and technical writing. Second edition. Frank Kerekes and Robley Winfrey. Ames, The Iowa state college press, 1951. 449 p. figs.
9. Yearbook of the West Indies and countries of the Caribbean, 1950. London, Thomas Skinner & co. ltd. (1950) 924 p. il. maps.
10. World almanac and book of facts for 1951. Edited by Harry Hansen. New York, New York World-telegram, 1951. 912 p. (For use in library only)

BIOLOGY—GENETICS

11. Report of a symposium on the use of isotopes in biological research. Sponsored by the Committee on growth of the National research council. Chicago, University of Chicago, 1947. v.p. figs. (processed)

11 (a). An atlas of the chromosome numbers in animals. Second edition, revised and enlarged from the original Tokyo edition. Sajiro Makino. Ames, Iowa state college press, 1951. 290 p. (processed)

BOTANY

12. Plant embryology: Embryogeny of the Spermatophyta. Donald Alexander Johansen. Waltham, Mass., Chronica botanica company, 1950. 305 p. References through the text. (New series of plant science books edited by Frans Verdoorn, Vol. XXIV)
13. New orchids from Africa. V. S. Summerhayes. (Harvard university. Botanical museum leaflets, vol. 14, no. 9, March 13, 1951, pp. 215-261)
14. Singapore. Botanic gardens department. Annual report. M. R. Henderson. Singapore, 1950. 6 p.
15. The flowering plants of the Anglo-Egyptian Sudan. F. W. Andrews. Volume I. Cycadaceae-Tiliaceae. Published for the Sudan government. Arbroath, Scotland, T. Buncle & co. ltd., 1950. 237 p. figs.
16. National botanic gardens of South Africa. Report and accounts. Kirstenbosch, 1951. 20 p.
17. The background of plant ecology. Henry S. Conard. A translation from the German, The plant life of the Danube Basin. Anton Kerner. Ames, Iowa state college press, 1951. 238 p.
18. An introduction to the anatomy of seed plants. Ernest L. Stover. Boston, D. C. Heath & co., 1951. 274 p. figs. References at end of chapters.

BOTANY—Concluded

19. Studies in growth and cellulolytic enzymes of tricholoma, with special reference to mycorrhiza formation. Birgitta Norkrans. Uppsala, 1950. 126 p. figs. (Symbolae botanicae upsalienses. XI, 1,) references: pp. 116-126.
20. Cytological and embryological studies in Arctic Poae. Axel Nygren. Uppsala, 1950. 64 p. tabs. map. pl. Literature cited: pp. 58-60. (Symbolae botanicae upsalienses. X, 4)

CHEMISTRY—CHEMIC TECHNOLOGY

21. Ion exchange resins. Robert Kunin and Robert J. Myers. New York, Wiley, 1950. 212 p. figs. tabs. references pp. 174-193.
22. American society of brewing chemists. Proceedings of the annual meeting, 1950. Chicago, 1951. 205 p. figs. tabs.
23. Partition chromatography; a symposium . . . organized and edited by R. T. Williams, assisted by R. L. M. Synge. Cambridge, University press, 1950. 103 p. figs. tabs. References at end of chapters, and supplementary bibliography: pp. 97-103. (Biochemical society symposia no. 3)
24. Encyclopedia of chemical technology. Edited by Raymond E. Kirk and Donald F. Othmer. Volume 6: Explosives to furfural. New York, Interscience, 1951. 1008 p. figs. tabs.
25. Colorimetric determination of traces of metals. Second edition, revised and enlarged. E. B. Sandwell. New York, Interscience, 1950. 673 p. figs. tabs. (Chemical analysis; a series of monographs on analytical chemistry and its application. Volume III)
26. Safflower; agronomic, processing, and economic data. S. Kellenbarger, R. L. Albrook, and A. H. Harrington. Pullman, 1951. 22 p. (Washington state institute of technology. Division of industrial research. Bulletin no. 210. Washington A.E.S. bulletin no. 521)
27. Dehydrated mashed potatoes—a review. R. L. Olson and W. O. Harrington. Albany, California, Western regional research laboratory, 1951. 23 p. (processed) (U.S. Department of agriculture. Bureau of agricultural and industrial chemistry. AIC-297)
28. The determination of vitamin A in margarine. J. Boldingh and J. R. Drost. Zwijndrecht, Netherlands, Lever brothers & Unilever N.V., 1950. 9 p. (processed)

COOPERATION—CREDIT

29. American cooperation, 1950. Wash., American institute of cooperation, 1950. 809 p.
30. Year book of agricultural co-operation. Edited by The Horace Plunkett foundation. Oxford, Basil Blackwell, 1950. 337 p. Selected bibliography of co-operation . . . pp. 326-337.
31. The poor man's prayer; the story of credit union beginnings. George Boyle. New York, Harper, 1951. 207 p.
32. Saskatchewan. Department of co-operation and co-operative development. Sixth annual report, 1950. Regina, 1951. v.p.
33. An economic analysis of the tax status of farmer cooperatives. John H. Davis. Wash., American institute of cooperation, 1950. 128 p. bibliography: pp. 125-128.

CROPS

34. Judging crop quality. George H. Dungan and Oren E. Bolin. Danville, Ill., Interstate, 1950. 288 p. il. tabs.
35. America's crop heritage. Nelson Klose. Ames, Iowa state college press, 1950.156 p. il. tabs.
36. Mustang oats. I. M. Atkins. College Station, 1950. 10 p. figs. (Texas agricultural experiment station. Bulletin 728)
37. Sugar beet production in the Red River Valley. Roy M. Gilcreast. Fargo, 1950. 48p. figs. tabs. (North Dakota agricultural college. Agricultural experiment station. Bulletin no. 363)
38. Better forage for Alaska; a progress report. William J. Sweetman, and others. Palmer. 1950. 19 p. il. tabs. (Alaska. University. Agricultural experiment stations, Circular 12)
39. Pasture management investigations. Ford S. Prince and Paul T. Blood. Durham, 1950. 15 p. (New Hampshire. University. Agricultural experiment station. Circular 81)
40. Pedigree strains of pasture plants. L. Corkill. Palmerston North, Department of scientific and industrial research. Grasslands division, 1950. 15 p. il. (Grasslands bulletin no. 3)

DAIRY INDUSTRY—DAIRY RESEARCH

41. Tests for milk, cream, butter, cheese, ice cream and dairy by-products. Division of bacteriology and dairy research. Ottawa, 1950. (Canada. Department of agriculture. Publication 611. Farmers' bulletin 56, revision)
42. Ontario cheese producers' association. Report of the eighteenth annual meeting, 1951. (Belleville) 1951. 32 p.
43. New Zealand dairy products marketing commission. Third annual report and statement of accounts, 1950. Wellington. 96 p. il.

ECONOMICS—ECONOMIC PLANNING—ECONOMIC STUDIES

44. The rural economy of New England, a regional study. John Donald Black, with the assistance of the Committee on research in the social sciences and the Graduate school of public administration of Harvard university. Cambridge, Harvard, 1950. 796 p. tabs. maps. graphs. Bibliographical footnotes.
45. The economics of collective action. John R. Commons, with a biographical sketch by Selig Perlman. New York, Macmillan, 1950. 414 p. col. front. Bibliography of the writings of John R. Commons: pp. 377-407.
46. New England research news: Report on research activities in New England in agricultural economics. Nineteenth annual issue. Boston, The New England research council on marketing and food supply, 1951. 33 p. (processed)
47. Cuba. T. Brimelow. London, H.M. stationery office, 1950. 90 p. (Great Britain. Board of trade. Overseas economic surveys)
48. The Marshall plan; a program of international cooperation. Prepared by Lewis Paul Todd for The advisory committee on education, Economic cooperation administration. Wash., 1950. 63 p. il.
49. The economic report of the President . . . to the Congress, January 12, 1951 . . . Wash., U.S. Govt. printing office, 1951. 241 p.
50. Western farm economics association. Proceedings of the twenty-first annual meeting, Davis, California, 1948. n.p. 183 p. (processed) (Library has also Proceedings of the twenty-third annual meeting, 1950)
51. Point four, Latin America and European dependencies in the Western hemisphere; a selected bibliography of studies on economically undeveloped countries. Wash., 1950. 110 p. (U.S. Department of state. Division of library and reference services. Bibliography no. 55)

ENDOCRINOLOGY—HORMONES

52. Scandinavian congress for endocrinology, First, Stockholm. Papers, parts 1 and 2. (In Acta endocrinologia, vol. V, nos. III and IV, 1950)
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54. Recent progress in hormone research. Proceedings of the Laurentian hormone conference. Volume V. Edited by Gregory Pincus. New York, Academic press, inc., 1950. 537 p. figs. tabs. References through the text.

ENGINEERING

55. Laboratory design. National research council report on design, construction and equipment of laboratories. Edited by H. S. Coleman. (Published for) National research council. Committee on design, construction and equipment of laboratories. New York, Reinhold, 1951. 393 p. il. figs.
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ENGINEERING—Continued

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FEEDING AND FEEDING STUFFS

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71. Digestibility experiments with various feeds for dairy cattle. II. Folke Jarl. Tierp, 1950. (Sweden. K. Lantbrukshögskolan och statens lantbruksförsök. Statens husdjursförsök. Meddelande Nr 44) English summary: pp. 56-58)

FERTILIZERS

72. Organic surface cultivation; its theory and practice. N. Gerard Smith. London, Ward, Lock & co., ltd., 1950. 192 p. il.
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74. The production of micronutrient deficiencies in plants grown in sand culture and the effects of some of these deficiencies on plant growth. Eric J. Hewitt. Use of Aspergillus Niger for determining magnesium, copper, zinc, molydenum and manganese in soils and plants. D. J. D. Nicholas. London, 1950. 44 p. figs. (The fertiliser society. Proceedings no. 10)
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FOOD

77. Food research under the Department of scientific and industrial research. F. Kidd. (Royal society. Proceedings, series B, vol. 138, no. 890. February 15, 1951 pp. 31-47)
78. Seasonal patterns of food consumption, city families, 1948. Wash., 1951. 17 p. (processed) (U.S. Department of agriculture. Bureau of human nutrition and home economics. Special report no. 3)
79. Great Britain. Overseas food corporation. Report and accounts, 1949-50. London, H.M. stationery office, 1950. 121 p.
80. Report of the Canadian committee on food preservation, 1950. Ottawa, v.p. figs. tabs. (processed) At head of title: National research council of Canada, Dominion department of agriculture, Fisheries research board of Canada. (To be used in library only)

FORESTS AND FORESTRY—FOREST PRODUCTS

81. Forest products; the harvesting, processing, and marketing of materials other than lumber, including the principal derivatives, extractives, and incidental products in the United States and Canada. Nelson Courtlandt Brown. New York, John Wiley & sons, inc., 1950.
82. Forest products research guide. Fourth edition. Wash., National lumber manufacturers association. Standing committee on products and research, 1950. 335 p. (processed)
83. Northeastern loggers' handbook. Fred C. Simmons. Wash., 1951. 160 p. figs. (U.S. Department of agriculture. Agriculture handbook no. 6)
84. Southwestern trees; a guide to the native species of New Mexico and Arizona. Elbert L. Little, jr. Wash., 1950. 109 p. figs. (U.S. Department of agriculture. Agriculture handbook no. 9)
85. Introducing wood facts for all who handle it. Harold T. Eyres. London, Sir Isaac Pitman & sons, ltd., 1950. 258 p. figs.
86. Tree growth and rainfall—a study of correlation and methods. Waldo S. Glock. Wash., 1950. 47 p. (Smithsonian miscellaneous collections, vol. 111, no. 18)
87. Nati onal shade tree conference, Syracuse, New York, 1950. Western chapter National shade tree conference, Long Beach, California, 1950. Proceedings of annual meetings. Wooster, Collier printing co., 1950. 310 p.

HORTICULTURE

88. Dahlia cultivation. N. Gerard Smith. New York, Pellegrini & Cudahy inc., n.d. 96 p. il.
89. La taille des arbres fruitiers. Paul Champagnat. Paris, Librairie agricole, horticole, forestière et ménagère, 1949. 217 p.
90. A fruit-grower's diary. Raymond Bush. London, Faber and Faber ltd. (1949) 248 p. il.
91. The lily year book 1948. London, Royal horticultural society, 1948. 135 p. figs. (No. 12)
92. Plant life. Vol. 7, 1951. Edited by Hamilton P. Traub and Harold N. Moldenke. Stanford, California, The American plant life society, 1951. 173 p. figs.
93. Lawn problems of the Southwest . . . Howard J. Dittmer. Albuquerque, 1950. 76 p. (New Mexico. University. Publications in biology. No. 4)
94. The gladiolus annual, 1951. Harrow, England, The British gladiolus society. 115 p. il.
95. A survey of the Horticultural research station, 1922-1949. R. M. Woodman. Cambridge, 1951. 24 p. (Cambridge. University. School of agriculture memoirs. No. 22)
96. Connecticut vegetable growers' association. Proceedings of the thirty-seventh annual meeting, 1949. n.p. 81 p.
97. The fruit, the seed and the soil. Collected edition of the John Innes leaflets. Edited by Cyril D. Darlington. Edinburgh, Oliver and Boyd, 1949. 90 p. figs.
98. Kansas state horticultural society. Biennial report, 1950. Topeka, 1950. 157 p. (Volume 50)
99. Lignin for golf greens and other horticultural uses. I. V. Anderson. Missoula, 1951. 4 p. (processed) (U.S. Department of agriculture. Forest service. Northern Rocky Mountain forest and range experiment station. Research note no. 87)
100. Virginia state horticultural society. Proceedings of the fifty-fifth meeting, Roanoke, 1950. Staunton, 1951. 286 p. il.
101. How to landscape your grounds. Loyal R. Johnson. New York, A. T. De La Mare, 1950. 257 p. plans. figs.
102. Alpine garden society year book, 1951. Farnborough, 1951. 106 p.
103. Organic soil management for vegetables. F. S. Browne. Ottawa, 1950. 36 p. il. tabs. (Canada. Department of agriculture. Publication 853)
104. American cranberry growers' association. Proceedings of the eighty-first annual convention, 1950. (Pemberton), New Jersey 23 p.
105. Culinary herbs. Alan E. Littler. Victoria, 1950. 5 p. (processed) (British Columbia. Department of agriculture. Horticultural branch. Horticultural stencil no. 16)
106. Canadian gladiolus society 1950 annual. (Guelph) 1951. 178 p. il.
107. Rhododendrons, azaleas, magnolias, camellias & ornamental cherries. A. T. Johnson. London, My garden, 1948. 93 p. il.
108. Holland. Ministere van landbouw, visserij en voedselvoorziening. Tuinbouwgids, 1951. The Hague, 1951. 844 p. il. tabs.
109. Delphinium. The book of the American delphinium society for 1950. Cleveland, 1950. 106 p. il.
110. State horticultural society of Pennsylvania. Proceedings of the ninety-first annual meeting, 1950. 102 p.

INSECTS—PESTS

111. Field and laboratory experiments with insecticides against locust hoppers. C. J. B. Smit. Pretoria, 1949-50. 78 p. tabs. (South Africa. Department of agriculture. Science bulletin no. 304)
112. Hawaiian entomological society. Proceedings for 1950. Honolulu. (Vol. XIV, no. 2, March, 1951, pp. 203-341)
113. Dual spray equipment for airplane spraying tests. J. M. Miller and D. A. Isler. Wash., 1951. 4 p. figs. (processed) (U.S. Department of agriculture. Bureau of entomology and plant quarantine. ET-294)
114. The protection of buildings and timber against termites. W. D. MacGregor. London, 1950. 41 p. figs. pl. (Great Britain. Department of scientific and industrial research. Forest products research bulletin no. 24)
115. Field tests on a number of old and new insecticides against Thrips tabaci Lind. (Thysanoptera) attacking cotton seedlings and onion in Egypt. Abd El-Aziz Ali El-Sayed Ghabn. (Société Fouad Ier d'entomologie. Bulletin, 43e année, 1950, pp. 173-242)

LIVE STOCK—ANIMAL BREEDING

116. History of dairy shorthorn cattle. George T. Burrows. New York, Vinton & company, ltd., 1950. 176 p. il.
117. Sheep farming. Allan Fraser. London, Crosby, Lockwood & son, ltd., 1950. 173 p. il. (Fifth edition)
118. The care of light horses. John M. Kays. Columbia, 1950. 39 p. figs. (Missouri. University. Agricultural experiment station. Circular 353)
119. Goose raising. A. S. Johnson. Ottawa, 1950. 11 p. figs. (Canada. Department of agriculture. Publication 848)
120. The relationship between egg shape and hatchability in meat type strains of New Hampshire. W. C. Skoglund. Newark, 1951. 6 p. il. (Delaware. University. Agricultural experiment station. Bulletin no. 287, technical)
121. The Hope Holsteins; a study of breeding of Holstein (Friesian) cattle at Hope agricultural station, Jamaica. T. P. Lecky. Kingston, 1950. 111 p. (Jamaica. Department of agriculture. Bulletin no. 44, n.s.)

MICROSCOPY

122. Précis de microscopie . . . M. Langeron. Septième édition. Paris, Masson et cie, 1949. 1430 p. figs. Bibliographie générale: pp. 1397-1398.

NUTRITION—VITAMINS

123. Symposia on nutrition of The Robert Gould research foundation, inc. Volume II. Plasma proteins. Edited by John B. Youmans. Springfield, Charles C. Thomas, 1950. 352 p. figs. tabs. Bibliography at end of each paper.
124. Teaching better nutrition; a study of approaches and techniques. Prepared by Jean A. S. Ritchie. Wash., Food and agriculture organization of the United nations, 1950. 148 p. il (F A O nutritional studies no. 6)
125. Nutritive requirements and feed formulas for chickens. H. R. Bird. Wash., 1950. 28 p. figs. tabs. (U.S. Department of agriculture. Circular no. 788, revised)
126. Second conference on nutrition problems in Latin America, Rio de Janeiro, Brazil, 1950. Report. Wash., Food and agriculture organization of the United nations, 1950. 34 p.
127. The animal metabolism laboratory of the University of New Hampshire. Nicholas F. Colovos. Durham, 1950. 6 p. fold. (New Hampshire. University. Agricultural experiment station. Circular 82)
128. Comparison of the 2,6-Dichlorophenolindophenol and 2,4-Dinitrophenylhydrazine methods with the Crampton bioassay for determining vitamin C values in foods. Elizabeth M. Hewston and others. Wash., 1951. 30 p. figs. pl. (col.) (U.S. Department of agriculture. Technical bulletin no. 1023)

PARASITOLOGY—PATHOLOGY

129. An illustrated laboratory manual of parasitology. Raymond M. Cable. Minneapolis, Burgess publishing co., 1950. 152 p. figs. (rev. ed.)
130. The pathogenesis and pathology of viral diseases. Edited by John G. Kidd. Symposium held at the New York academy of medicine, December, 1948. New York, Columbia university press, 1950. 235 p. figs. tabs. References at end of each paper.

PHYTOPATHOLOGY

131. Diseases of vegetable crops. rev. ed. J. C. Walker. Ann Arbor, Edwards bros., 1950. 67 p. (processed)
132. Virus diseases and some symptomologically related abnormalities of the vine. S. J. Du Plessis. Stellenbosch. 33 p. il. (Stellenbosch. University. Annals, vol. XXVI, section A, no. 13, 1950)
133. The smut fungi; a guide to the literature, with bibliography. George William Fischer. New York, Ronald press company, 1951. 387 p. bibliography: pp. 221-377.
134. Biological characters of plant pathogens temperature relations. Kogo Togashi. Tokyo, Meibundo, 1949. 478 p. Literature cited: pp. 335-466.
135. Target leaf spot of the hevea rubbertree in relation to host development, infection, defoliation, and control. J. B. Carpenter. Wash., 1951. 34 p. figs. (U.S. Department of agriculture. Technical bulletin no. 1028)
136. Some plant responses to certain insecticides in the soil. Arthur C. Foster. Wash., 1951. 41 p. fig. tabs. (U.S. Department of agriculture. Circular no. 862)

TEXTILES

137. Wool year book, 1950. London, Textile mercury limited, 1950. 634 p. il.
138. Wool, 1949-50. Sydney, N.S.W., Birt and company (pty.) ltd., 64 p. il. tabs.
139. The Australian wool board. Fourteenth annual report, 1950. Melbourne, 1950. 24 p. il.

VETERINARY MEDICINE

140. Diseases of the pig and its husbandry. David J. Anthony. third edition. London, Baillière, Tindall and Cox, 1950. 309 p. figs. References to literature: pp. 295-296.
141. Surgical techniques for veterinary students. W. F. Guard. Columbus, Ohio, 1948. (Edwards brothers, inc., Ann Arbor, Mich., litho-printers) 179 p. il. (processed)
142. Poultry; sanitation and disease control, the complete guide to sanitation and treatment of disease. B. F. Kaupp. 4th edition, revised, by B. F. Kaupp and R. C. Surface. Minneapolis, Kaupp and Surface, 1950. 493 p. il. pl. (col.)
143. The veterinarian in public health. Oscar Sussman. (Association of food and drug officials of the United States. Quarterly bulletin, vol. XV, no. 1, January 1951, pp. 8-12)
144. Great Britain. Ministry of agriculture and fisheries. Animal health services. Report, 1948. London, H.M. stationery office, 1950. 51 p.

WEEDS

145. Western weed conference, Twelfth. Proceedings, Denver, Colorado, 1950. n.p. (1950) 140 p. (processed)
146. Chemical weed control. A. E. Roland. Halifax, 1950. 49 p. figs. (Nova Scotia. Department of agriculture and marketing. Publication 1012)
147. Steps toward effective weed control. H. E. Wood, P. J. Olson, G. L. Shanks, and H. A. Craig. Winnipeg, 1951. 15 p. il. tabs. (Manitoba. Department of agriculture and immigration. Publication no. 238)
148. How about TCA? A new weed killer for grasses. Robert B. Balcom. (The reclamation era, vol. 37, no. 1, pp. 6-7, 18, 1951)

WILDLIFE

149. North American wildlife conference, Fifteenth. Transactions, 1950. Wash., Wildlife management institute, 1950. 681 p. il.

ZOOLOGY

150. Taxonomic keys to the common animals of the north central states exclusive of the parasitic worms, insects and birds. Samuel Eddey and A. C. Hodson. Minneapolis, Burgess publishing co., 1950. 123 p. il. (processed)
151. The chordates. Herbert W. Rand. Phila., Blakiston, 1950. 862 p. figs.
152. Early embryology of the chick. Bradley M. Patten. fourth edition. Phila., Blakiston, 1951. 244 p. figs. pl. (col.) bibliography: pp. 213-234.

NEW PERIODICALS IN LIBRARY:

The journal of pharmacy and pharmacology. London, The Pharmaceutical society of Great Britain.
Zeitschrift für angewandte mathematik und physik. Basel, Switzerland.
Operational research quarterly. London, Operational research club.
Planta. Archiv für wissenschaftliche botanik. Berlin.
Textile world. Albany, McGraw-Hill.
Survey of current business. Wash., U.S. Department of commerce. Bureau of foreign and domestic commerce.
Economica. London, London school of economics.
Meteorologische rundschau. Organ der Meteorologischen gesellschaft Bad Kissingen. Berlin, Springer-Verlag.
Entomologist's gazette. London, Watkins and Doncaster.
Suelo Tico. Revista del Ministerio de agricultura e industrias. San José, Costa Rica.
The Manchester school of economic and social studies. London.
Journal of clinical pathology. London, British medical association.
Abstracts on agricultural and horticultural engineering. Wrest Park, Silsoe, Bedfordshire, National institute of agricultural engineering.
International chemical engineering and process industries. London, Leonard Hill limited.
L'agronomie tropicale. Paris, Ministère de la France d'Outre-Mer.